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approved by	Anna Okello, Research Program Manager

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List of Acronyms

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
ADPS	Agriculture Development Policy and Strategy
AGFORS	ASEAN Agroforestry Smallholders Syndicate
AUD	Australian Dollar
AVID	Australian Volunteers for International Development
CARD	Capacity Building for Agriculture and Rural Development
CAVA-FAO	Climate Change Adaptation in Wetland areas in Lao PDR
CBID	Community Based Inclusive Development
CSU	Charles Sturt University
DAFO	District Agriculture and Forestry Office
DFAT	Department of Foreign Affairs and Trade
DLF	Department of Livestock and Fisheries
DNA SNP	DNA Single Nucleotide Polymorphic Marker
ERS	School of Environmental and Rural Science
EWAII	The East-West Corridor Agriculture Infrastructure Improvement
FAO	Food and Agriculture Organisation
FECRT	Faecal Egg Count Reduction Test
FHH	Female Headed Household
FMD	Foot and Mouth Disease
GDP	Gross Domestic Product
GOL	Government of Laos
GRRC	Goat and Rabbit Research Centre
HDR	Higher Degree Research
HPA	Health Poverty Action
HUAF	Hue University of Agriculture and Forestry
IFAD	International Fund for Agricultural Development
LA	Learning Alliance
LAK	Lao Kip
Lao PDR	Lao People's Democratic Republic
LPB	Luang Prabang
LRC	Livestock Research Centre
LWT	Liveweight
MAD	Mobile Acquired Data
MAF	Ministry of Agriculture and Fisheries
NAFRI	National Agriculture and Forestry Research Institute
NAHL	National Animal Health Laboratory
NGO	Non-Government Organisation
NIAS	National Institute of Animal Science
NLA	National Learning Alliance
NUOL	National University of Laos
PAFO	Provincial Agricultural and Fisheries Offices
PCR	Polymerase chain reaction

PPR	Peste de Petit Ruminants
R4D	Research for development
RDT	Research Discussion Tool
RQ	Research Question
SE Asia	South East Asia
SIDA	Swedish International Development Authority
SKU	Savannakhet University
SRA	Small Research Activity
SSI	Semi Structured Interview
SVK	Savannakhet
UNE	University of New England
VTE	Vientiane
WWF	World Wide Fund for Nature

1 Acknowledgments

The project team would like pay a special tribute to Dr Doug Gray who passed away prematurely on July 20, 2023. Doug was the initiator of the SRA that preceded this project and was an active member of the project team in the formative early stages of this project. Doug's ideas and calm, deliberative and humorous personality are sorely missed.

The early stages of the project in Laos were greatly facilitated by the support of Dr. Bounthong Bouahom (former Director General of NAFRI) Dr. Vanthong Phengvichith (former deputy director of NAFRI). We also acknowledge and thank Dr. Chay Bounphanouxay the Director General NAFRI for her ongoing support of the project during its life.

The project owes a major debt of gratitude to the approximately 70 project farmers. These farmers endured monthly visits and monthly survey questionnaires during much of the project as well as answering three very much longer benchmarking surveys at the beginning, middle and end of the project. Animals were supplied for DNA sampling, ear tagging, regular weighing, and in some cases, wearing of GPS collars for 12 months with monthly capture, collar removal, data retrieval and battery changing. Despite this there was a very low attrition rate of farmers withdrawing from the project.

We also thank busy members of the following NGOs for their participation in the Learning Alliance. The Poverty Reduction Fund, International Labour Organisation, World Vision, WWF, IFAD, SAFE (Stability of Altered Forest Ecosystems), CAVA-FAO (Climate Change Adaptation in Wetland areas in Lao PDR), and CBID (Community Based Inclusive Development USAid) and EWAII (The East-West Corridor Agriculture Infrastructure Improvement). Staff from Savannakhet University also attended.

Not listed in the original project document, but critical to the many of the outcomes of our project are the 4 postgraduate students attached to the project. We thank Sang Van Le, Preethinie Jayasekara, Eoin Liehr and Chanh Van Nguyen for being such an integral part of the project, participating in most project meetings and events and helping deliver many important project outcomes.

The project was based in Savannakhet and we thank the Heads of Section at PAFO Savannakhet (Mr Khamchanh Sidavong and Ms Orlavanh Samathmanivong) for their support of the project in providing many facilities for project use and key staff who were involved in nearly all of the project field work in the province. Key staff were Mr Thonglai Vannivong Mr Phonesavanh Phommasone, Ms Tingkham Mingmuangsen and Ms Sophaphone Phommachack.

Dr Bounmy Phiewvankham was the initial named contact between the project and the local Savannakhet University. This role was taken up later by Mr Phonetheb Porsavathdy who proved to be an enthusiastic and effective interlocuter between the project and SKU. This led to SKU students becoming involved in numerous project training events, meetings and project associated student projects.

A key technology utilised in the project was mobile acquired data acquisition (MAD) using the CommCare platform. We are grateful to Dr David McGill from the University of Melbourne for providing CommCare training to project staff at physical training sessions in Armidale, Vientiane and Hanoi as part of his own ACIAR project.

Another key technology used in the project was GPS tracking devices and collars worn by goats. The devices were designed and built by Mr Glen Charlton at UNE and he and fellow Precision Agriculture Group member Derek Schneider made major contributions to the project during the development, testing and validation of the devices and collars and the success of the method owes much to their insights and skills.

2 Executive summary

This project was developed in response to the rapid growth of goat populations of Lao PDR driven largely by demand from neighbouring Vietnam. It sought to identify and manage risks and support opportunities associated with this growth under four broad objectives.

Objective 1 was to evaluate goat production systems in Lao PDR to develop technical, social and economic benchmarks against which improvements can be assessed. Work was concentrated in 3 districts of Savannakhet province and involved 70 smallholder goat farmers in 7 villages and four somewhat larger commercial farms. Monthly visits and three major benchmarking surveys were carried out using mobile acquired data methodology, enabling a detailed characterisation of the main goat production systems, the productivity of goats and the socioeconomic context in which goat raising operates. They also enabled measuring change over time. Key aspects of the smallholder system were reliance on unsupervised grazing of often communal land (low cost), uncontrolled breeding, housing at night, competition for time and resources with other farm enterprises, moderately good growth and reproductive performance but excessive mortality, and strong demand for goats by visiting traders with little requirement to take goats or their products to market.

Objective 2 was to assess major constraints and identify and evaluate potential solutions. Inbreeding due to uncontrolled breeding in small herds had been identified as a possible constraint by Lao Government representatives but a detailed genomic study of 420 goats revealed this to be unlikely. GPS tracking of goats over a 12-month period identified mixing of goats between herds within villages and defined the size of home ranges and factors affecting this. Disease and mortality were frequently identified as a major constraint and detailed studies using a case-control design with molecular diagnosis identified the most common causes of the endemic orf-like syndrome, pinkeye and chronic pneumonia. Gastrointestinal nematode infections tended to be moderate rather than severe overall and the anthelmintics available have maintained efficacy. Effective control of these conditions was achieved during the project, but the lack of veterinary infrastructure and availability of appropriate treatments calls control into the future into question. Improvements in basic housing and husbandry resulted in reduced disease incidence. Seasonality of feed availability was a major constraint and establishment of fodder plots was implemented on many holdings but lack of productivity and persistence of the plots over the dry season limited their effectiveness. Typical grazing times allowed are also shorter than recommended. Farmers embraced the use of subsidized mineral blocks and a small-scale farmer trial on supplementation of grower goats provided encouraging results. Dog attacks, vehicle accidents and theft were all problems encountered by farmers but the project did not specifically address any of these.

Objective 3 was to reduce market risk and increase marketing opportunities through improved understanding of the factors affecting demand and pricing of goats in Lao PDR and Vietnam. To address these two desktop reviews of goat production and marketing regionally and worldwide were conducted and major surveys of farmers, traders, abattoir owners, restaurant owners and consumers in Vietnam and Laos were undertaken using mobile acquired data methodology. These revealed that goat is a comparatively expensive but desirable meat, consumed mostly in restaurants and that income was a major determinant of willingness to pay for mountain goat meat in both Vietnam and Laos. In the case of Vietnamese restaurants more goats were purchased live and slaughtered on the premises than purchased as carcasses The primary supply is local goat traders with goats nearly exclusively originating from Vietnam (79%) or Laos (21%). Interestingly there was no preference for Lao goats over Vietnamese goats and, contrary to previous understanding, the origin of goat meat was not an important consideration amongst consumers. Prospects for ongoing high demand for goat meat are good, but will be dependent on economic conditions, particularly in Vietnam. Across border trade in goats between Laos and Vietnam

is largely unregulated and it is unclear if such regulation is feasible in the near future or desirable from a smallholder viewpoint.

Objective 4 was to build capacity for research and development of goat production in Lao PDR and initiate scaling out of project findings. Despite the middle years of the project being adversely affected by COVID-19 travel restrictions numerous farmer, extension worker and researcher training activities were conducted in the areas of mobile acquired data methodology, gender awareness, goat husbandry and health practices, fodder plot establishment, parasitology and cross farm visits. Project findings were extended to other NGOs via a Learning Alliance in Laos. The project supported many undergraduate student projects at Savannakhet University and the National University of Laos. Two PhD and one Master's student at UNE were supported by the project, with two of these from Vietnam. The main barrier to taking on postgraduates from Laos was English language competency. Initial scaling out of the project findings was successful, both to neighbouring non-project farmers and via links to other NGOs through the Learning Alliance.

Goat raising in Laos and Vietnam has grown rapidly in recent decades in the absence of major government initiatives and this is likely to continue into the future. In Laos, support for improved goat housing, provision of improved animal health services, provision and distribution of subsidised pasture seeds and improvement of communal grazing lands to boost the productivity of cattle, buffalo and goats using them would increase productivity of the sector without placing excessive demands on the scarce resources and time of smallholder farmers. Prospects for large scale, intensive meat goat production systems in Laos are hindered by the lack of readily available low-cost feed inputs. Such systems are increasing in Vietnam and Thailand where feed resources are more readily available.

3 Background

The core issue for this project was to manage risks and support opportunities associated with very rapid growth of the goat populations of Lao PDR (Laos) and Vietnam. The ACIAR SRA (LPS/2016/027 Assessing goat production and marketing systems in Lao PDR and market linkages into Vietnam; Oct 2016 - Oct 2018) reviewed current knowledge and understanding of goat production and marketing in Laos and conducted initial research and consultations in this area[1] The SRA confirmed the rapid increase in goat numbers and intense interest in the sector in Laos and determined that the main driver is increased demand from Vietnam. Field surveys on goat production and marketing conducted in 27 villages from 14 districts in 5 provinces: Savannakhet, Khammouane, Houaphan, Oudomxay and Luang Prabang confirmed key features of goat production such as small herd size (10.3 ± 5.3), the use of goats for sale (94%) rather than home consumption, sale almost exclusively to traders (96.3%), sale mostly to meet a specific expense (eg. school or hospital fees) and the significant proportion of family income provided (35 ± 16%). On the production side it revealed the predominance of free grazing unrestrained year-round in available forest/bushland (52%) but universal provision of housing at night (100%), the limited use of forage supplementation (26%) but universal use of salt within the goat house (100%), individual ownership of breeding males (1.13 bucks/family), very low use of introduced bucks (3.7%), the long period of growth to a sale weight of approx. 20 kg (13.4 months) and the perceived importance of disease as the major constraint (1st ranked by 93% of farmers). Authorities in Laos identified inbreeding in small family herds as a likely significant contributor to the comparatively low growth rates of Lao native goats, and this was identified as an important research question to resolve.

The survey confirmed the high demand for goats in the cities of Laos and from many centres in Vietnam. Results also confirmed the lack of inputs to the mainly smallholder farmers who supply the market. During the survey and on subsequent field visits a small number of more commercially oriented farmers were identified. All farmers shared the same constraints of high mortality of young and mature goats with the figures ranging from 10% to 80%, as reported during interviews. Disease signs such as diarrhoea (potentially parasitic) bloat and mouth lesions (presumably Orf) were common. Better definition of the extent and causes of mortality and their control was identified as an important research question.

Three important market chains from Laos to Vietnam were described North Eastern via Route 6, a Northern, via route 7 and a Southern via route 9. Through interviews with farmers, traders, abattoir owners and restaurateurs along these market chains in Laos, and along the southern market chain to Quang Tri and nearby provinces details of the high demand were captured. On average there is a 30% price premium for goats originating in Laos compared with local mostly crossbred Vietnamese goats. There is anecdotal evidence of consumer preference for Lao provenance due to better taste and an image of being clean and green. It is often sold as ‘Lao Mountain Goat’. The provenance attributes and potential for market branding expansion or protection need to be researched. Average estimated values ascertained for a 20kg male goat along the southern export value chain to Vietnam are $114 (AUD) at the farm, $146 on arrival at the slaughterhouse in Vietnam (with 1 or 2 trader transactions between) and $163 after slaughter. Farmers are thus capturing approximately 70% of the slaughtered value of the animal. In Vietnam the best cuts of goat meat can retail at over $20/kg and the cheapest at around $10/kg. However, sale of goat meat direct to consumers is limited with the vast majority of meat from slaughterhouses going directly to restaurants where considerable additional value adding occurs. Border

[1] *Douglas Gray et al., Assessing goat production and marketing systems in Laos and market linkages into Vietnam. Final Report of Project LPS/2016/027, Australian Centre for International Research (Canberra: Australian Centre for International Research, January, 2019 2019).*

controls for goat export appeared to be only partly implemented with significant informal movement of goats across the border to escape licence fees. An important research need is to better define the goat value chains and factors affecting them. Of particular importance is the basis of the premium for Lao type village goats and the extent to which breed improvement programs, particularly using exotic genotypes may compromise this.

Following a SRA review workshop in June 2017 in Luang Prabang, evaluation of data from longitudinal studies was undertaken to obtain more objective data on current goat production and marketing. Two collaborating organisations agreed to take part. One was the ASEAN Agroforestry Smallholders Syndicate (AGFORS) which was undertaking an initiative to integrate goats in forestry plantations. The other was Health Poverty Action (HPA) which implemented a project funded by Australia to supply goats and support goat enterprises in Savannakhet. Analysis of data from these sources revealed lower annual mortality rates (12-31%) than recorded in the field survey indicating a likely response to the higher level of management available on these projects. However, measures of kids born per year per breeding doe (1.2-1.4) were approximately 50% of the conventional estimates of 1.7 kids per mature doe every 8 months (2.55 kids/doe/year). This suggests an important need for actual measurement of key production system indices rather than relying on survey data. This would also facilitate benchmarking of enterprise performance against realistic targets.

Based on the needs identified by the SRA, a concept note with the same title as the final project was submitted to ACIAR in August 2017 with 8 objectives. Following many iterations with ACIAR and project partners the final project proposal emerged with 4 clear objectives namely:

1. Evaluate goat production systems in Lao PDR to develop technical, social and economic benchmarks against which improvements can be assessed.
2. Assess major constraints and identify and evaluate potential solutions
3. Reduce market risk and increase marketing opportunities through improved understanding of the factors affecting demand and pricing of goats in Lao PDR and Vietnam, and of the associated value chains
4. Build capacity for research and development of goat production in Lao PDR and initiate scaling out of project findings

The key partners in the project proposal were the University of New England (UNE) as the implementing agency in Australia, supported by Charles Sturt University (CSU). In Lao PDR the implementing agency was the National Agriculture and Forestry Research Institute (NAFRI) supported by National Animal Health Laboratory (NAHL), with Hue University of Agriculture and Forestry (HUAF) and the National Institute for Animal Science (NIAS) as the joint agencies in Vietnam. Based on the resources available, and the presence in Northern Loas of the ADB Northern Smallholder Livestock Commercialisation Project 2014-2021[2] the focus area of the new project was Savannakhet province in the South, the province in Laos with the highest goat population.

This proposal was underpinned by government policies in Laos, Vietnam and Australia. In Laos the proposal is aligned with Agriculture Development Policy and Strategy (ADPS) 2025[3] and agreed country priorities between the GOL and ACIAR as presented in the ACIAR Annual Operation Plan 2017/18.

In Vietnam, the proposal was guided by the recently released ACIAR-Vietnam Research collaboration strategy 2017-2027. The project is a good fit with *Research Theme 4 (Market*

[2] *http://www.adb.org/projects/documents/northern-smallholder-livestock-commercialization-project-pam.*

[3] *Agriculture Development Strategy to 2025 and Vision to the year 2030, Ministry of Agriculture and Forestry, Government of the Lao People's Democratic Republic, May 2015*

engagement), particularly *point 2 "Improvement in Agrifood value chains through understanding of efficiencies and constraints ……"*. The project aimed to characterise the major goat value chains within Vietnam and identify constraints, risks and opportunities for innovation. Cutting across these sectoral strategies in both countries was a shared commitment to gender equity and gender sensitive approaches to ensure that significant inequities in the distribution of costs and benefits between men and women along the value chain are identified and appropriate responses made.

The immediate challenges and opportunities for the goat sector were to manage risks associated with the very rapid growth in goat populations of Laos and Vietnam. Potential risks include collapse of export market to Vietnam or premiums for Lao goat, low productivity and efficiency, disease, over exploitation of communal forage resources, and social costs. Opportunities include meeting market requirements to maintain high prices and demand, improving productivity and returns on labour and livelihood diversification. Goat numbers in Laos have increased dramatically in recent years although population estimates vary. According to FAOSTAT[4] numbers increased more than fivefold between 2000 and 2016 from 30,700 to 157,000. The last Laos Agricultural Census in 2010/11 estimated goat numbers to be 215,600 (MAF, 2014)[5] while current estimates of the current goat population range up to 550,000[3]. Almost all of this increase has been in small enterprises in rural communities and the majority of product is exported to Vietnam. In Vietnam numbers increased from 1.23 million to 1.84 million between 2011 and 2015[6]. Demand in Vietnam is likely a function of both population growth (19% increase 2000-2016 from 77.6 m to 92.7 m) and increased GDP per capita, PPP (constant 2011 international $) of 228% from $2,562 m to $5,838 over the same period[7]. The price paid for 'Lao-type' goats, typically > AUD $6.00/kg live weight, is a price premium of 15-25% and up to 45% over other goat types[8]. The sustainability of this trade requires improved understanding of the basis for the price premium and the risks associated with the export trade. The potential environmental risks from unconstrained goat production expansion with and without intensification also need to be assessed. There is a need to develop sustainable production systems that can meet this demand and position the sector for a long productive future.

Key dates in the project development and progression.

- 30/08/2017 - First submission of project concept note (Phase 1)
- 21/09/2018 - First submission of the full project proposal (Phase 2)
- 29/05/2019 - Project Head agreement between ACIAR and UNE signed
- 09/03/2022 - Variation 1 to the project was signed on. This extended the project by 6 months to 30/12/2023 without additional funding, mostly due to COVID-19 induced delays.

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[4] FAOSTAT accessed March 2018.

[5] MAF 2014. Lao PDR Lao Census of Agriculture 2010/11: Analysis of Selected Themes, Vientiane, October 2014. Ministry of Agriculture and Forestry, Government of the Lao People's Democratic Republic.

[6] NIAS 2017. National Institute of Animal Sciences (NIAS), Hanoi, Vietnam. Unpublished current livestock census data.

[7] World Bank Databank accessed March 2018.

[8] Hoang, N, et al (2017) Understanding Goat Market Chains between Southeast Laos and Central Vietnam. In 'North West Vietnam Research Symposium 'Mountains of Opportunity'. Hanoi, Vietnam 22-24 November 2017.Australian Centre for International Research, Canberra.

4 Objectives

The overall aim of the project was to enhance income-generating opportunities for goat raising households in Lao PDR through the development of productive, environmentally sustainable, socially acceptable and gender sensitive production systems accessing high-demand goat meat markets in Vietnam.

To contribute to this aim, the project was designed with 4 objectives, to address 10 underlying research questions as follows.

Objectives

1. Evaluate goat production systems in Lao PDR to develop technical, social and economic benchmarks against which improvements can be assessed. (RQ1, 2 and 3).
2. Assess major constraints and identify and evaluate potential solutions (RQ 4, 5 and 6)
3. Reduce market risk and increase marketing opportunities through improved understanding of the factors affecting demand and pricing of goats in Lao PDR and Vietnam, and of the associated value chains (RQ 7 and 8)
4. Build capacity for research and development of goat production in Laos and initiate scaling out of project findings (RQ 9 and 10)

Underlying Research Questions

1. What are the production and socioeconomic characteristics of smallholder, large and agroforestry production systems with goats in Laos?
2. How can benchmarks derived from research question 1 be used to identify technical and social constraints within each farming system and practices to overcome these?
3. What are the opportunities and risks created by the emergence of small commercial goat farms and community agroforestry enterprises involving integration of goats with forestry in Laos
4. Is smallholder production in Laos constrained by inbreeding and what are the opportunities and risks for genetic improvement to increase production and quality?
5. To what extent is goat production and marketing in Laos constrained by mortality and disease, and what “best practice” methods for disease control can be integrated into goat systems?
6. To what extent is goat production in Laos constrained by undernutrition and, how can improved forage production and feeding practices be integrated into goat systems?
7. What are the factors affecting demand and pricing of goats along the value chain in Laos and Vietnam?
8. Is demand for live goats and goat products from Vietnam and Laos likely to change in the foreseeable future and what are the characteristics of the product needed to meet likely future demand?
9. What skills, technologies and practices are needed to enable producers, traders and other players in the goat value chain in Laos and Vietnam to benefit equitably from improved goat production and marketing.
10. What capacity building is required to initiate scaling out of research findings?

5 Methodology

5.1 Project Administration and People

Governance and management of the Project followed the same participatory principles that underpin the research and have guided the preparation of the proposal. The project team has had monthly online meetings via Zoom throughout with meeting outcomes and action points minuted. These have proved very useful and have been well attended by Lao, Vietnamese and Australian project team members, including the students on the project.

The teams addressing each of the objectives have been stable on the Lao and Vietnamese side with more change evident in the early stages of the project amongst Australian participants. This included the losses of Drs Romana Roschinsky and Michelle Carnegie from the project and reduction in input of Drs Priscilla Gerber and Fran Cowley due to other commitments. Additions to the project team during this period were the appointment of Dr Luisa Olmo as the project scientist, Mr Thaixiong Xaikhue as the project veterinarian in Laos, introduction of Dr Emilio Morales (value chain specialist - UNE) and A/Prof David McNeill (animal nutrition – UNE) to the team and increasing the time on the project of Dr Alison Colvin.

An overview of the leadership within the project and main people involved in its implementation is provided in Table 5.1.

Table 5.1. Main staff (surnames only) involved in leadership and implementation of the project objectives. A full list of project personnel and affiliations can be found at Appendix 1

Objective	Leadership	Implementation
1	Phengsavanh (NAFRI)/Walkden-Brown (UNE)	Laos – Phengvilaysouk, NAFRI/PAFO/DAFO field teams Australia (UNE) - Olmo and Colvin
2	Walkden-Brown/ Theppangna (NAHL)	Laos - Phengvilaysouk, Phengsavanh, PAFO/DAFO staff, Theppangna Australia (UNE) - Olmo, Xaikhue, Gerber, Colvin, Sang Le*, Jayasekara*, Charlton, Schneider, Van de Werf, Heras-Saldana, Chanh*, McNeill, Walkden-Brown Australia (NSW DPI) –Jenkins
3	Hoang (UNE)	Vietnam - Van, Ba and supporting staff (HUAF), Cuc, Don and supporting staff (NIAS), Nga (HUA) Laos - Phengvilaysouk, NAFRI supporting staff Australia (UNE) - Hoang, Morales, Olmo, Colvin
4	Millar (CSU)/ Phengsavanh (NAFRI)	Laos - Phengsavanh, Phengvilaysouk PAFO/DAFO staff Australia (CSU) - Millar Australia (UNE) - Olmo, Colvin, Liehr*

* Postgraduate student working on the project

The original intent of the project to hold annual coordination meetings in different countries was thwarted by the COVID-19 pandemic and associated travel restrictions during in 2021 and 2022. Instead, the following major project meetings occurred or are scheduled to occur during the life of the project.

- 24-25 October, 2019. *Project Inception meeting*, Sengtawan Riverside Hotel, Vientiane, Lao PDR
- 25-27 October, 2021. *Mid project review meeting*. Online using Zoom
- 7-10 November, 2022 *Project coordination meeting*. PAFO and Daosavanh Hotel, Savannakhet, Lao PDR
- 16-17 October 2023. *End of project review meeting*. Online using Zoom

5.2 Objective 1: Evaluate and benchmark goat production systems in Lao PDR

The purpose of evaluating and benchmarking the production systems was to develop technical, social and economic benchmarks against which improvements can be assessed both during the life of the project and beyond the project. This part of the project was carried out in selected villages and small-scale farms in Savannakhet province. Two main approaches to benchmarking performance were used viz:

- Detailed survey questionnaires of project participants at the beginning, middle and end of the project (Benchmarking surveys).
- Monthly visits to households with a short questionnaire for owners (Monthly household survey), and measurement of a small number of individually identified goats (Monthly doe and kid surveys).

In addition, quarterly surveys of the environment and gastrointestinal parasite burdens were carried out. The latter is described under Activity 2.2. The timing of the different survey types is shown in Figure 5.1. Survey questionnaires can be found in Appendix 2 to 8.

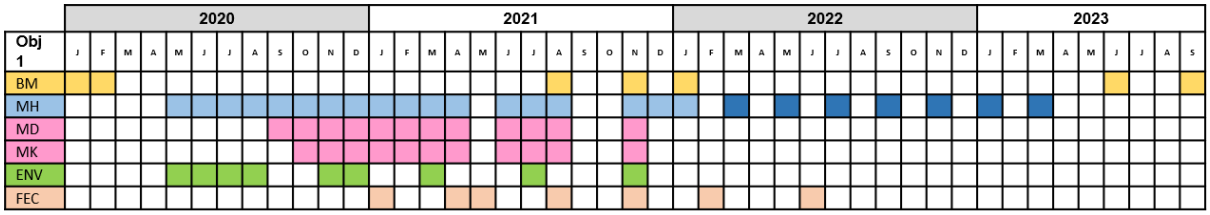

Figure 5.1: Timing of Objective 1 activities over the sampling period January 2020 to September 2023. Abbreviations: BM – Benchmarking survey, MH – Monthly household survey, MD – Monthly doe survey, MK – Monthly kid survey, ENV – Environment survey, FEC – Faecal samples. Bimonthly survey is indicated by dark blue shading within Monthly survey period.

5.2.1 Study sites and village selection

The project is focused on smallholder goat production in the lower Mekong basin in the central region of Lao PDR (Savannakhet province) which contains the highest proportion (16%) of the country's goat population of 682,000[9]. Goats in Lao PDR are predominantly

[9] *"Food and Agriculture data," Food and Agriculture Organization of the United Nations, 2022, accessed April 2022, 2022, https://www.fao.org/faostat/en/#data/QCL.*

raised by smallholder farmers and the main breed in production is the small native *Kambing-Katjang* goat[10,11,12].

Villages from Sepon (*n* = 1), Phin (*n* = 3) and Songkhone (*n* = 3) districts (Fig. 5.2 and Table 5.1) were recruited into the project. NAFRI project members selected these districts as they are on the main highway to Vietnam, providing access to the goat export trade. NAFRI staff joined local Provincial and District Agriculture and Forestry Office (PAFO and DAFO) staff and local village headmen in January 2020 to purposefully select 6 villages based on the criteria that:

1. Villages had many goats,
2. A high proportion of households in the village had goats,
3. The village leader, committee and farmers were willing to participate in the four-year project and,
4. Lack of goat feed was viewed as a limitation to productivity.

Table 5.1: Villages recruited into the project.

Farm type	District	Village	Village population	HH in village	Number keep goats	% HH keeping goats	Est. number goats in village
Smallholder	Phin	Na Po	500	119	40	34	150
		Nhon Nhang	1279	290	80	28	400
		Xa Loi	505	90	80	89	400
	Songkhone	Sebanghiang	2685	384	40	10	320
		Songkhone	1364	235	50	21	300
		Nhonsomphou	1010	192	16	8	80
	Sepon	Kanglouang	294	47	21	45	105
Large farm	Kaison	Dongdamdouane	422	-	-	-	-
		Nateuy	-	-	-	-	-
	Songkhone	Nhonsomphou LF	1010	-	-	-	-

Three villages in Phin district (Xa Loi, Nhon Nhang and Na Po) and three from Songkhone district (Songkhone, Nhonsomphou and Sebanghiang) were selected while eight villages were rejected because either only few farmers being willing to participate, goat production was not a priority or few households kept goats. Ten households per village were selected based on the criteria that households:

1. Had at least 5-6 goats,
2. Were interested in participating and
3. Had labour and land to support future interventions

This resulted in 60 households being recruited. A seventh village, Kanglouang, from a third district, Sepon, was opportunistically added because households from this village were

[10] *B. Kounnavongsa, V. Phengvichith, and T.R. Preston, "Existing goat production systems in Khammouane province Lao." (Master of Science Masters, University of Tropical Agriculture, 2010).*

[11] *P. A. Windsor et al., "The endoparasitism challenge in developing countries as goat raising develops from smallholder to commercial production systems: A study from Laos.(Report)(Survey)," Veterinary Parasitology 251 (2018), https://doi.org/10.1016/j.vetpar.2017.12.025.*

[12] *G. D. Gray et al., Final Report: Assessing goat production and marketing systems in Laos and market linkages into Vietnam. (Canberra: Australian Centre for International Agricutlural Research, 2019).*

participating in agroforestry which was deemed important to understanding the diverse goat management systems. Data on village attributes can be found in Appendix 9.

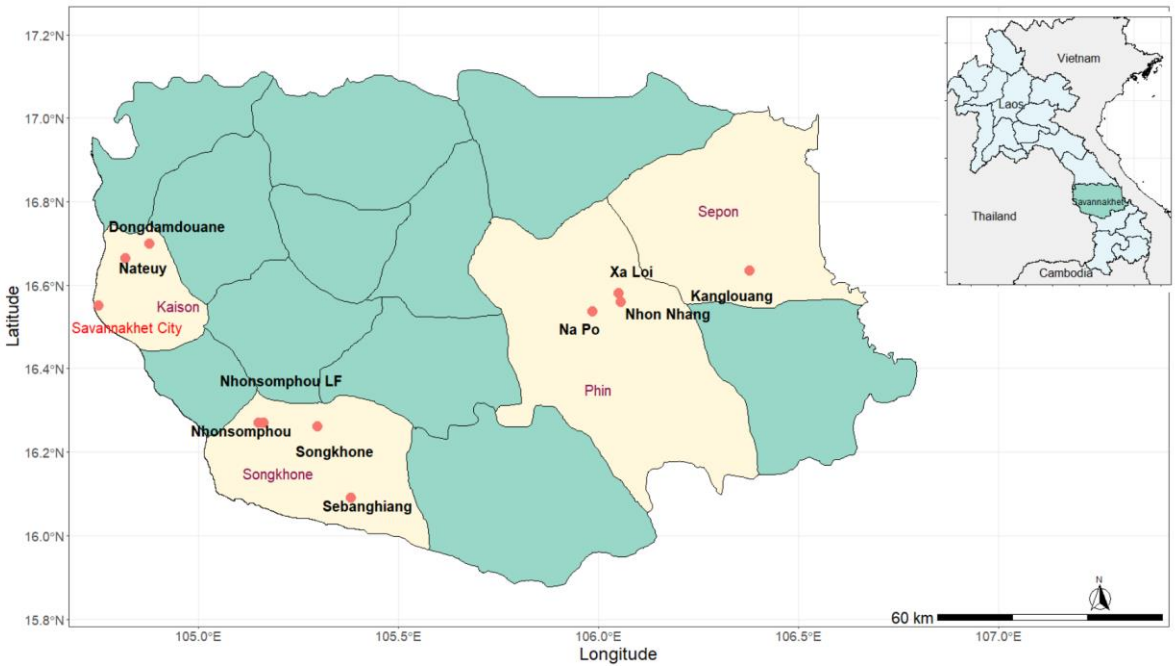

Figure 5.2: Map of Lao PDR with Savannakhet Province and the study districts highlighted

5.2.2 General survey methodology and Mobile acquired data using CommCare

Participation was voluntary and participants were free to withdraw from the project or any project activities at any time without consequence. Participant information sheets were made available and verbal consent to participate in the project and specifically for each of the surveys was recorded electronically at the initial interview of each survey type.

The survey interviews were conducted in person by NAFRI staff with the aid of DAFO and PAFO staff and Thaixiong Xaikhue.

A mobile acquired data (MAD) methodology was chosen for use in all data collection using online survey building platform CommCare® (Dimagi Ltd., Cambridge, MA, USA) installed on tablets carried by the survey staff. The CommCare® software allowed for longitudinal tracking of project households and their goats and allowed all surveys to be read in English and Lao script which enabled Lao enumerators to interview respondents and record answers in Lao language, but have the responses available in English. Enumerators synched collected data to the server via the cloud, so data was available for export almost instantaneously when mobile service was available. This significantly reduced the workload of the Lao team and expedited data checking and analysis as they did not need to enter information collected on paper forms into a spreadsheet. It also reduced potential mistakes during data entry. Lao enumerators were trained in the use of the CommCare® apps on android tablets prior to use in the field. Lao government restrictions on travel during peak infection periods of the COVID-19 pandemic (April – May 2021 and September – October 2021) impacted continuous data collection for all surveys.

5.2.3 Benchmarking surveys

Three benchmarking surveys (BM) were conducted, one at the start of the project, one at the mid-point and one at the end of the project period. The BM were designed to evaluate smallholder goat production systems in Savannakhet province, with the 1st BM (BM-1)

providing a benchmark against which to measure change in socioeconomic situations and goat husbandry practices over the course of the project. The 2nd and 3rd benchmarking surveys (BM-2 and BM-3) provide a measure of change with reference to BM-1. Questions in the BM referred to the previous 12 months and involved over 120 questions mostly closed, and some open questions, in seven sections;

1. Household information (including level of education and farming and livelihood system)
2. Goat enterprise characterisation (goat numbers, changes to herd size, goat management system and gender roles)
3. Goat raising problems
4. Goat enterprise decision making
5. Motivation/sustainability/confidence
6. General goat herd information (months of kidding and replacement breeding stock)
7. Goat husbandry practices

Core questions were maintained in each survey questionnaire to allow longitudinal comparison between the 3 survey iterations. BM-2 included some clarifying questions based on data analysis from BM-1 and a section on the impacts of the COVID-19 pandemic on goat production. BM-3 contained an additional section to assess the project impacts and farmer perceptions of the project.

BM-1 was conducted on smallholders from the 6 initially selected villages Na Po, Nhon Nhang, Xa Loi, Sebanghiang, Songkhone and Nhonsompou in January and February 2020, the 7th village of Kanglouang in Sepon district was interviewed in May 2020. Three commercial 'Large farms' in Savannakhet province, 2 in Kaison and 1 on Songkhone districts, were also interviewed for BM-1 in March 2020. Interviews were conducted in person in the farmer's village using a mobile acquired data (MAD) app built in CommCare. The interviews took between 1 to 1.5 hours per respondent to complete. The interviews were conducted by NAFRI staff with the aid of DAFO and PAFO staff.

BM-2 was conducted in stages due to restrictions on travel during the COVID-19 pandemic and flooding in the survey areas. The first group of farmers were interviewed for BM-2 in November 2021 with the final group of farmers interviewed in January 2022. The commercial 'Large farms' were not interviewed for BM-2.

Interviews of the registered smallholder farmers for BM-3 commenced in June 2023 but was only completed in September 2023 due to farmer availability during the rice planting season.

The benchmarking surveys were approved by the human ethics committee of the University of New England (approval number HE19-218).

5.2.4 Monthly household surveys

The monthly household surveys (MH) of the registered project farmers commenced in May 2020 and continued monthly until January 2021. During that 21-month period there were 3 months where no data were collected and only 18 households were sampled in April 2021 due to COVID-19 travel restrictions (See Appendix 10). The MH consisted of questions pertaining to herd numbers, total, births, deaths, losses, sales, sale price, purchases, disease syndrome present at the herd level, mortality reasons and use of project interventions. Key productivity indicators (KPI) were calculated from these data. Only monthly data observations between May 2020 and January 2022 were included in the MH analysis in Appendix 10 and due to a large variation in the number of records per farmer, the KPI for each farmer were adjusted based on farmer record number (multiplying KPI by 18/n number of records) and annualised (by multiplying by 12/18). Inclusions for data analysis of the MH were that farmers had to have at least 8 records over the 18 sample dates and have

5 or more goats. The MH took an average of 20 minutes per household per month to complete.

The monthly household survey was approved by the human ethics committee of the University of New England (approval number HE20-002).

5.2.5 Monthly doe survey and monthly kid survey

The monthly doe survey (MD) and monthly kid survey (MK) were designed to measure doe bodyweight, kid growth rates and mortality reasons. Initially, 2 does and their kids were selected per household and the same animals were recorded each month and replaced if necessary. The does were randomly selected from all does > 6 months old. Any new offspring of the does were registered each month between September 2020 and August 2021. If a doe exited the herd, a replacement doe > 6 months was randomly selected and registered. The individual does and their kids (2-3/household) from each household were ear-tagged and were monitored at the monthly visits for pregnancy/lactation status, bodyweight, condition score, disease syndromes, and reasons for mortality if dead. The MD and MK were conducted over ten months from September 2020 to November 2021 (COVID-19 restrictions meant smaller numbers observed in April 2021 and no observations for May, September and October 2021). The monthly kid and doe surveys took between 1 and 5 minutes each to complete per farmer per month.

The monthly doe and kid surveys were approved by the animal ethics committee of the University of New England (approval number AEC20-006)

5.2.6 Quarterly village environmental survey

The quarterly village environmental survey was designed to measure the impact of goat rearing and changes in goat numbers on the local village environment. Village leaders were interviewed for the survey and were asked a series of questions including:

- changes in livestock numbers,
- changes in available grazing land,
- subjective assessment of pasture/fodder availability in common grazing areas, bare ground and erosion
- damage to crops by goats
- goat rearing effects on water quality
- photos of selected sites at each quarterly survey.

The survey commenced in May 2020 and was completed in July 2021. Initially, the Lao team conducted the Environmental survey every month from May 2020 to August 2020. A total of 8 surveys were conducted in the survey period.

5.3 Objective 2: Assess major constraints and identify and evaluate potential solutions

Based on the preceding SRA and consultations with the Lao Government the project identified three major constraints to investigate with each constituting an activity under this objective as follows:

- Activity 2.1 Determine the importance of inbreeding depression in smallholder production systems.
- Activity 2.2 Determine the importance and causes of mortality and disease in Lao goat production systems, identify and test control methods

- Activity 2.2 Improved forage and feeding systems in smallholder and agroforestry production systems

All activities were undertaken on the cooperating project farms/households described under Objective 1 with details of the methodology of each provided in the sections below. PhD students were heavily involved in activities 2.1 (Sang Van Le) and 2.2 (Preethinie Jayasekara).

5.3.1 Activity 2.1 Determine the importance of inbreeding depression in smallholder production systems

Two approaches were taken to addressing this issue. The first approach was based on DNA sampling genotyping of animals from the project villages (DNA study). The second approach was to place GPS collars on selected goats in 5 of the project villages to determine the extent of ranging and mixing behaviour of goats from different family groups during grazing.

DNA genotyping study

For the DNA study a total of 420 ear-notch samples were collected from February to April 2022 on goats from 140 households in Savannakhet as shown in Table 5.2. Inclusion criteria were

2. Sample 3 female or male goats aged < 12 months old
3. Do not select goats that are full siblings
4. Do not select parents and their offspring

Table 5.2: Locations and numbers of goats to collect ear-notch samples from smallholder farms in Savannakhet Province.

District	Village	Households	No. of samples/ household	No. of samples/ village
Phin	Xa Loi	20	3	60
	Nhon Nhang	20	3	60
	Na Po	20	3	60
Songkhone	Songkhone	20	3	60
	Nhonsomphou	20	3	60
	Sebanghiang	20	3	60
Sepon	Kanglouang	20	3	60
Total				**420**

Samples were stored frozen at NAHL then shipped to New Zealand for genotyping using the goat 50K Illumina BeadChip by GenomNZ at AgResearch, Mosgiel, New Zealand.

To assess the genetic diversity of Lao goats with other Global goat breeds, we combined the genotype data from the Lao goats with genotype information from published reference

datasets of other goats breeds worldwide[13,14,15,16] The global dataset contained 5688 samples from 165 populations in xxx countries. A subset of Asian goat populations contained dataset included 1552 samples from 43 populations in Asia.

Quality control of genomic was performed in PLINK v1.9[17] before further analysis, leaving 419 samples from Lao goats available for analysis.

Genetic diversity was estimated by expected (He) and observed (Ho) heterozygosity as well as the genetic distance between populations which was measured in as F_{ST} in PLINK while the level of inbreeding was assessed by the genomically derived inbreeding coefficient (F_{IS}). We looked at genetic variation and genetic distances between population in the global dataset, the Asian dataset, and within the Lao dataset.

Genetic diversity was estimated by expected (He) and observed (Ho) heterozygosity as well as the genetic distance between populations which was measured as FST in PLINK while the level of inbreeding was assessed by the genomically derived inbreeding coefficient (FIS). We looked at genetic variation and genetic distances between population in the global dataset, the Asian dataset, and within the Lao dataset.

GPS Study

Following development and testing of GPS dataloggers and collars at UNE and in Laos (see previous Annual reports) a total of 42 GPS collars were deployed to track goats from five villages in Songkhone, Phin and Sepon over a 12 month-period from August 2022 to July 2023 (Table 5.3).

Table 5.3: Number of GPS collars to be deployed on goats per district in Savannakhet province, Lao PDR

Districts	Villages	Households	Goats/ Household		Goats/ village
			Male	Female	
Songkhone	Sebanghiang	3	1	2	9
	Songkhone	3	1	2	9
Phin	Xa Loi	3	1	2	9
	Nhon Nhang	3	1	2	9
Sepon	Kanglouang	2	1	2	6
Total					**42**

[13] *Licia Colli et al., "Genome-wide SNP profiling of worldwide goat populations reveals strong partitioning of diversity and highlights post-domestication migration routes,"* Genetics Selection Evolution *50 (2018).*

[14] *H Berihulay et al., "Genetic diversity and population structure in multiple Chinese goat populations using a SNP panel,"* Animal genetics *50, no. 3 (2019).*

[15] *Tatiana E Deniskova et al., "SNP-based genotyping provides insight into the West Asian origin of Russian local goats,"* Frontiers in genetics *12 (2021).*

[16] *Vera Mukhina et al., "Genetic Diversity, Population Structure and Phylogeny of Indigenous Goats of Mongolia Revealed by SNP Genotyping,"* Animals *12, no. 3 (2022).*

[17] *Shaun Purcell et al., "PLINK: a tool set for whole-genome association and population-based linkage analyses,"* The American journal of human genetics *81, no. 3 (2007).*

GPS collars were set to record the position at 5 minute-intervals (24 hours a day). When a goat was sold, lost, or died during the period, another goat from the same herd was randomly selected to wear the GPS collar.

The GPS recorded the position (longitude, latitude, and altitude coordinates), date and speed estimate of the goat in the memory card. Every thirty day, the battery and memory cards were replaced by a fully charge battery and a new memory card. The data from recorded memory card were retrieved.

Quality control of raw GPS data was performed in Python before further analysis. The distance and speed instantaneous values were calculated based on haversine method.

Home range and core use areas will be estimated using kernel density estimates with adehabitatHR package[18].

5.3.2 Activity 2.2 Determine the importance and causes of mortality and disease in Lao goat production systems, identify and test control methods

Several approaches were used to investigate the issue of mortality and its causes in goats. These included:

- Inclusion of disease and mortality related questions in the Benchmarking and Monthly Household surveys (Objective 1 methodology and results)
- Internal parasite prevalence study to determine major gastrointestinal genera affecting goats, the prevalence and severity of infection and influences on faecal egg counts (This is the quarterly goat parasite survey mentioned under Objective 1).
- Slaughter study to conduct total worm counts and speciation of worms detected
- Anthelmintic resistance study to benchmark the present efficacy of the 3 main classes of anthelmintic used to treat goats in Laos.
- Conducting a case-control study of the major syndromes affecting goats in the project area with molecular diagnostics to ascertain the main causative agents for the syndromes

Internal parasite prevalence study

The internal parasite prevalence study was conducted on random samples of goats (n = 472) owned by 44 of the households registered with the project. Faecal samples for faecal worm egg counts (FWEC) were collected in January, April, August and November 2021. WEC from pre-testing for the anthelmintic resistance study, collected in February and June 2022, were also included in the dataset. Faecal samples were analysed for WEC by trained local staff using a modification of the McMaster egg flotation technique. In order to determine the proportions of the genera of the strongyle eggs counted in the WEC, faecal samples within a village were pooled, moistened, mixed with vermiculite and incubated at 27ºC for 7 days. Larvae were recovered and, after iodine staining, were differentiated into genus (*Haemonchus*, *Trichostronglyus, Teladorsagia, Oesophagostamum, or Cooperia*). Ethics approval for the WEC prevalence was given by the animal ethics committee of the University of New England (approval number AEC20-006).

The WEC and larval culture data were analysed using the statistical package JMP 16.2 (SAS Inc, Cary, NC, USA). Farm characteristics (land size, goat herd size, farm type) and grazing management practices (goat management system, where goats are grazed, time

[18] *Clément Calenge, "The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals,"* Ecological modelling *197, no. 3-4 (2006).*

spent grazing in wet season and time spent grazing in dry season) were collected as part of a benchmarking survey of farm production systems (Objective 1). These explanatory variables were fitted in binomial Likelihood Ratio chi-square tests for each internal parasite identified in the WEC. Analysis of means for proportions were used where p-values were significant to 95%.

Slaughter/Total worm count study

The entire gastrointestinal tract and livers of 12 goats were collected from a restaurant in Savannakhet following frozen storage at -18 to -20°C. All goats were locally sourced Lao goats of the native breed.

Following thawing of the total contents of each of the abomasum, small intestine and the large intestine collected in a large jar, with multiple rinsings and the volume then made to a volume of 2 litres. Samples were agitated and a 100ml (5%) aliquot was taken from each stained with Lugol's iodine and all adult male and adult female nematodes in the sample were counted counted and differentiated to species level. Juvenile worms were also counted but not speciated. The worm counts were multiplied by 20 to derive the total worm count for each each animal.

Anthelmintic resistance study

A faecal egg count reduction test (FECRT) was conducted in 4 project villages (Na Po, Xa Loi, Songkhone and Sebanghiang) selected from the 7 project villages based on historically sufficient FWEC as identified by the internal parasite prevalence study. This FECRT was conducted in June and July 2021 which is the rainy/monsoon season in Lao. On day -7 FWEC was conducted on all male and female goats >5 months of age on each farm. From these samples 128 goats with the highest FEC values (>300 eggs/g) were selected and stratified into 4 treatment groups based on WEC (Table 5.4).

Table 5.4: Treatment groups with anthelmintic type and dose rate for faecal egg count reduction test.

Treatment	Anthelmintic	Dose rate	Dose method	Brand
1	Albendazole	5.625mg/kg	oral	Abentel® Suspension, Atlantic Laboratories Corporation Ltd, Samut Prakan, Thailand
2	Ivermectin	0.2mg/kg	subcutaneous	Ivomec®, Boehringer Ingelheim Animal Health South Africa Pty Ltd, Randburg, South Africa
3	Levamisole	7.5mg/kg	subcutaneous	Lemisol Veterinary®, Life Biopharma Sdn. Bhd., Seremban, Malaysia
4	Control	No treatment	-	-

Goats were weighed and treated with anthelmintics based on their bodyweight. Faecal samples for individual WEC and larval culture were taken at Day -7 and Day 0 before treatment and Day 14 after treatment. At every sample date a pooled faecal sample for each treatment in each village (n = 16) was used to identify larvae to genus status as described above. Inexperience of the technicians in differentiating *Teladorsagia* spp. from *Trichostrongylus* spp. for the FECRT means that data for these two genera will be combined. Each treatment group had n = 32 goats except for the control group (treatment 4) which had n = 31.

Faecal egg count reduction (FECRT) was calculated using the 'Resoloot calculator for Faecal Egg Count Reduction (2013)' which used the formula described (2, where T2 = Day 14 treatment mean WEC and C1 = Day 0 control mean WEC).

$$FECRT = 100 \times \left(1 - \frac{T2}{C1}\right) \quad (2)$$

Ethics approval for the faecal egg count reduction test was given by the animal ethics committee of the University of New England (approval number ARA22-009).

Case control study

A case control study was designed and implemented in the project goats (among small holder goat households (N= 70) to collect diagnostic samples and some epidemiological data in to help determine causation. The target sample size was calculated as 40 paired samples based on a matched case control study where cases (diseased) and matched control animals (healthy) were collected in a ratio of 1:1.

The case control study was started in January 2022 and was conducted by the field team led by Mr Thaixiong Xaikhue by visiting each of the project goat households on a monthly basis until sufficient samples were collected. During these visits, the health situation of project goats in the last month was assessed. The sample and survey data were uploaded real-time to a server using CommCare.

When project goats presented with clinical signs of syndromes of interest, samples from diseased goats were taken for laboratory diagnosis as indicated in Table 5.5. For each sample taken from a disease case, similar sample type was collected from a healthy goat as a control. Samples were transported to and stored at NAHL under appropriate conditions as presented in Table 1 until further processing.

Table 5.5 Details of case control study sample collection and storage.

Disease syndrome	Required samples	Transport conditions	Storage condition	Total no of samples collected
Ocular and corneal inflammation syndrome	Conjunctival swabs	In transport medium, ice-box containing ice/ice bricks (maintain samples at 4°C)	-20 °C freezer	100
Lip and facial dermatitis syndrome	If crusty scabs->1g of scabs+ skin scraping	In 90% ethanol, room temperature	Room temperature out of direct sunlight	82
	If moist lesions-swab from lesion + 1g epithelium	In transport medium, ice-box containing ice/ice bricks (maintain samples at 4°C)	-20 °C freezer	0
Respiratory syndrome	Nasal swabs	In transport medium, ice-box containing ice/ice bricks (maintain samples at 4°C)	-20 °C freezer	100
Perinatal diarrhoeic syndrome	Rectal swabs	In transport medium, ice-box containing ice/ice bricks (maintain samples at 4°C)	-20 °C freezer	10

Post perinatal diarrhoeic syndrome	Rectal swabs	In transport medium, ice-box containing ice/ice bricks (maintain samples at 4°C)	-20 °C freezer	22

Total genomic DNA and RNA were extracted from samples at the NAHL using commercial extraction kits, according to the manufacturer's protocol with necessary modifications. Extracted nucleic acid samples were transported in dry ice to the Elizabeth Macarthur Agricultural Institute (EMAI), Australia which has approved quarantine facility for nucleic acid testing. They were stored at -80 °C until PCRs were carried out.

Quantitative real time probe-based, SyBr-based and conventional PCR assays were used in the study in order to screen samples to obtain prevalence data, to determine the compatibility of SyBr assay before introduce to NAHL and to characterise pathogens by DNA sequencing respectively. Both in house assays from EMAI and previously published assays were used to detect most probable pathogens as indicated in the Table 5.6.

Table 5.6 Summary of tested pathogens and test method for each disease syndrome

Disease syndrome	SYBR Green rt-PCR	Probe based PCR	Conventional PCR
Ocular and corneal inflammation syndrome	Genus Mycoplasma Genus Chlamydia	Genus Mycoplasma Genus Chlamydia *Moraxella ovis* *Moraxella bovoculi* *Moraxella bovis* If samples positive for G. Mycoplasma and G. Chlamydia, *M. conjunctivae* *C. pecorum*	Genus Mycoplasma Genus Chlamydia *Moraxella ovis*
Lip and facial dermatitis syndrome	Dermatophilus congolensis	Genus Parapox virus Orf virus Bovine popular stomatitis virus Pseudocowpox virus	Dermatophilus congolensis Orf virus
Respiratory syndrome		Genus Mycoplasma *Mycoplasma capricolum capripneumoniae (Mccp)* *Mannheimia haemolytica* *Pasteurella multocida* *Mycoplasma ovipneumoniae* *Bovine respiratory syncytial virus (BRSV)* *Bovine parainfluenza 3 virus (BPI3)*	Genus Mycoplasma *Mannheimia haemolytica* *Pasteurella multocida*

All quantitative PCR reactions were performed in a QuantStudio ™ PCR system (Thermo Fisher Scientific, US). The fluorescence data obtained was analysed using QuantStudio ™ Design and Analysis Desktop Software (Version 1.5.2; Thermo Fisher Scientific, US).

5.3.3 Activity 2.3 *Improved forage and feeding systems in smallholder and agroforestry production systems*

Forage establishment

Farmers in the project villages were selected to start planting forages based on their willingness and experiences on finding feed for their goats. On-site training for farmers took place during monthly visits. During appropriate times of the year (wet season) staff took the

opportunity to train farmers on planting, management and utilization on the sites. The number of training events is summarised in Table 5.7 below.

Table 5.7: Number of training events for growing fodder for goat production.

Topic	Training events	No. of participants
Forage planting	10	90
Forage management	10	90
Forage utilization	10	100
Total		**280**

Seed was purchased distributed to target farmers for the first three years of the project, supplemented by provision of vegetative planting material from LRC and multiplication plots established at SKU. These multiplication plots (7000m^2) were a learning site for students and a source of planting materials for farmers. The 4 main forages targeted by the project were *Brachiaria* hybrid cv Mulato, *Panicum maximum* cv Ubon, *Paspalum atratum* cv Ubon and *Stylosanthes guianensis* CIAT 184)

There was also provision of seed of guinea grass and Mulato to two larger goat farms to start building up grazing areas.

Mineral block distribution

The project provided mineral blocks to project farmers to incentivise continued participation in monitoring surveys and to assess the effect on goat productivity. During the first three months farmers were provided with free blocks after which farmers had to meet 50% of the cost of the blocks. The project team started distributing mineral blocks in April 2021 and ceased in June 2023.

Nutrition trials - village learning activities

These trials were carried out in villages in late 2022 to investigate the effect of supplementary feed on goat performance and benefit of fattening native goats in smallholder farms. They also aimed to demonstrate improved feeding management and build up the champion farmers in villages. The trials were designed and implemented by the Lao project team.

Study 1: Grower goat feeding trial

The study started in December 2022, 31 grower goats (between 6 and 12 months of age) were selected from 7 villages to be fed a concentrate feed at 100g/goat/day. A further 4 grower goats were selected from 2 villages as controls (0 g/goat/day). Bodyweights and condition scores were taken in December 2022, then in January, February and March 2023. Average daily gain (ADG) was calculated using the following formula:

$$ADG = \left(\frac{\text{Bodyweight 2 - Bodyweight 1}}{\text{Number of days between measurements}} \right)$$

Study 2: Doe feeding trial

Fifty-two pregnant does were selected from 7 villages to be fed concentrate feed at 100g/goat/day and 7 pregnant does from 2 villages were selected as controls (0 g/goat/day). Bodyweights and condition scores were taken in December 2022, then in January, February and March 2023. ADG was calculated from bodyweights as per equation above.

Urolithiasis trial

In Vietnam, where fattening of domestic or Lao goats for market is growing in scale, there is anecdotal evidence of severe issues with obstructive urolithiasis (bladder stones) in male goats leading to emergency slaughter or death. The problem is hypothesised to be linked to the high P concentrations in pellets formulated for cattle and pigs, but fed to goats instead. This is also likely to be an issue with goats fattened in Laos, should such fattening start to take place there. UNE PhD student Chanh Van Nguyen has a special interest in resolving this issue and was supported by the project to conduct an experiment on it at the Goat and Rabbit Research Centre of NIAS in Hanoi. The study was designed to test the hypothesis that providing additional dietary calcium (Ca) in the form of powdered limestone to goats would increase faecal P reducing P availability and therefore reducing the risk of urolithiasis.

The study was conducted at Hanoi's Goat and Rabbit Research Centre from March 1 to May 3, 2023, with ethical approval from The University of New England (UNE) (ARA22-107). Initially, 42 six-month-old male Boer-cross goats with liveweight approximately 20 kg were treated for parasites and vaccinated against foot and mouth disease, hemorrhagic septicemia, and enterotoxaemia. They were individually housed and acclimated to a base diet of *Panicum maximum* grass and concentrate for 21 days. Ultrasonography excluded five goats with renal or bladder stones and one for low intake, leaving 36 for the trial. These goats, averaging 23 kg, were individually supplemented with one of six levels of Ca (0, 7.5, 16.7, 25.7, 34.5, and 43.1 g limestone/kg DM) against a high-P pelleted diet (4.2 g Ca and 7.1 g P/kg DM) fed *ad libitum*, with fresh *Panicum maximum* grass for 21 days. Seven goats were excluded due to urolithiasis (2), death (2) and poor intake (3). Post-trial, all goats were switched to a standard diet containing 1% ammonium chloride for 21 days to acidify urine, in compliance with UNE animal ethics committee advice. Feed intake and water intake was measured daily, Urine pH and liveweight weekly, and fecal, urine, and serum creatinine, Ca, P, Mg, K, Na, and Cl concentration at Day 0, 21, and 42.

5.4 Objective 3 Assessing value chains, reduce market risk and increase marketing opportunities

5.4.1 Activity 3.1 Desktop review (months 1-9)

Available information on international, regional and local trade in goats and goat meat and factors influencing it was reviewed including goat population data and marketing systems. The international and regional components were built on the information on the local trade in live goats between Laos Vietnam obtained during SRA LPS/2016/027. It was led by Nguyen Huu Van in consultation with other project members, and implemented by Nguyen Huu Van, Bui Thi Nga, Nguyen Viet Don, and Luisa Olmo. Dr Olmo also led a wider review of goat trading worldwide in the context of competing animal meat products. Both reviews are either published or in the process of being published (see Section 10.2).

5.4.2 Activity 3.2 Market surveys (months 6-18)

Consumers, restaurant owners, abattoirs and goat traders were surveyed to ascertain past, current and likely future demand for goats and goat meat, and factors affecting pricing and demand (Questionnaires in Appendix 11 to 14). Each survey had a separate questionnaire design and required separate Human Ethics Committee clearance at UNE. Dr Nam Hoang led the design of the questionnaires and their ethical clearance in consultation with the social science team of Drs Millar and Olmo. Social and cultural factors including gender were taken into account in the survey design and implementation including trade-offs and inefficiencies that are not necessarily economic in nature. As for Activity 3.2 MAD with CommCare was used as the data recording method and questionnaire design took the interface and automated data translation into account. The targeted number of each type of survey is summarised in the table below. Survey teams comprising a mix of economist and animal

production staff trained in social research methods by the project extension specialist used tablets and MAD to carry out the survey on a one-to-one interview basis during the survey period (Table 5.8).

Table 5.8: Number of people surveyed for each type of market survey in Lao PDR, Central Vietnam and Northern Vietnam.

Survey target	Numbers of people surveyed		
	Laos	Central Vietnam*	Northern Vietnam**
Consumer	291	258	251
Goat restaurant	22	54	32
Registered abattoir	15	03	18
Trader	7	17	14

*Quang Binh, Quang Tri, Thua Thien Hue, Da Nang, Ha Tinh, Nghe An
**Son La, Hoa Binh, Hanoi, Dien Bien

5.4.3 Activity 3.3 Market forecasting (months 18-34)

Data was analysed to capture past, current and likely future demand for goats in Laos and Vietnam, factors influencing demand and prices, and how future demand may be met culminating in a report. The project economists, led by Dr Hoang undertake formal data analysis and prepare the report in consultation with the animal production and social science teams. The likely environmental and social consequences of meeting future demand and the risks they comprise, was evaluated in the report. Consumer preference models were built based on survey data.

5.4.4 Activity 3.4 Characterising domestic and export value chains (months 6-40)

Value chain data was acquired using face to face surveys of people along the chain including those surveyed under Activity 3.3. In addition to those surveyed under Activity 3.3 the farmers and traders were surveyed in Lao PDR (Table 5.9). Questionnaires for these can be found in Appendix 14 and 15.

Table 5.9: Number of people surveyed for each type of value-chain survey in 4 main areas of consumption and export Lao PDR. VTE – Vientiane, S Export - Khammouane and Savannakhet, NE Export – Huapanh, N Export - Luangprabang and Oudamxai.

Survey target	Numbers surveyed in different value chains			
	Domestic VTE	S Export	NE Export	N Export
Goat farmer	14	148	0	27
Trader	01	03	0	03

Value chain surveys design, methodology and ethical clearance were undertaken contemporaneously with Activity 3.2 using the same approaches. Survey staff used tablets and MAD to carry out the survey on a one-to-one face to face structured interview basis during the survey period. Survey data was summarised and subjected to value chain analysis and comparison by Dr Nga in consultation with the Objective 3 team.

5.5 Methodology - Objective 4. Capacity building and scaling out

5.5.1 Activity 4.1 Develop and implement Learning Alliance

The **Learning Alliance** was established in February 2020 in Savannakhet with 4 members initially and increasing to 8 members overall with varied attendance. Five meetings were held over 3 years at the PAFO Savannakhet office. Members included The Poverty

Reduction Fund, International Labour Organisation, World Vision, IFAD, SAFE (Stability of Altered Forest Ecosystems), CAVA-FAO (Climate Change Adaptation in Wetland areas in Lao PDR), and CBID (Community Based Inclusive Development USAid) and EWAII (The East-West Corridor Agriculture Infrastructure Improvement). Staff from Savannakhet University also attended.

Meetings started with presentations from NAFRI/PAFO staff on goat husbandry topics, followed by discussion and updates from each NGO about what their villages were doing regarding goat husbandry. Evaluation forms were filled in by each participant on the most useful things they had learnt and what they would like to focus on for next meeting (see form at Appendix 16. Field visits were held on the 2, 3 and 4th meetings.

5.5.2 Activity 4.2 Tactical capacity training

Gender training was held from 19-21 January 2021 at the PAFO office and in the field for 16 participants by Dr. Phonevilay Sinavong. Participants were from the Livestock Research Centre, NAFRI, PAFO, DAFO, and Savannakhet University. Topics included; Gender and Agricultural Development; Gender Mainstreaming in goat raising/marketing; and Practice in Data Collection in one village. Trainees interviewed nine households raising goats on gender roles with raising goats. They compiled the information and presented key findings There was reflection on differences between conventional interviews/data collection and interviews using a gender lens. Then a group discussion on how to use new gender awareness in their work and in the project. Three evaluation questions were posed and suggestions for future training. Report available at Appendix 17.

Extension methods training was held on the job as staff worked with village communities and individual farmers. Guidelines on how to run effective cross visits and how to develop case studies were delivered by Dr Joanne Millar in Laos to LRC and district staff on 22 July, 25 July, and 11 November 2022.

Farmer training by LRC and PAFO staff included how to grow and use forages (2 days in each village in late May/early June 2020 (see Appendix 18), goat nutrition and feeding from 19 – 21 July 2021 (see report in Appendix 19), how to build goat pens (using demonstration pens), supplementary feeding with pellets (30 farmers involved plus field day to present results in March 2023), and animal health advice on each monthly visit to project and non-project households. Farmers involved in the village learning activity feeding trial (Activity 2.3) were given scales and shown how to weigh their goats before sale to better negotiate sale price.

Technical writing course was not held. Mentoring in writing papers occurred during drafting online.

5.5.3 Activity 4.3 Strategic capacity building

From its inception the project actively sought to recruit postgraduate students particularly from Laos and Vietnam to bolster capacity building in the partner countries. UNE had guaranteed two PhD stipends to successful applicants and specific advertisements were placed and publicised by the project. Students were also encouraged to apply for Crawford Fund scholarships. In Laos prospective postgraduate students were identified and supported to apply in various ways including English language training.

The project also actively sought to support student projects in Laos. Scholarships to undertake specific goat-related research projects were offered at SKU (3) and NUOL (1) with applications scrutinised by a panel of experts on the project.

Students in these universities were also involved in initial testing of GPS goat collars in Laos and at SKU in the establishment and management of fodder crops appropriate for goats.

5.5.4 Activity 4.4 Initiate scaling out

Village meetings were held twice a year to organise farmer training, the benchmarking surveys and share information. **Cross visits** for 18 project farmers were held on 14 November 2022 in Phin district and 16t November 2022 in Songkhone districts (see reports in Appendix 20 & 21). Nine project farmers were taken to Nateuy large goat farm on 16 March 2023 (Appendix 22). On 27 April 2023, 12 CBID farmers and 7 staff visited Nhonsomphou and Sebanghiang villages (see reports in Appendix 23). **Impacts** were evaluated using group feedback sessions, staff interviews and monitoring practice changes in 2023 (See Appendix 20-23).

6 Achievements against activities and outputs/milestones

Objective 1: To evaluate goat production systems in Lao PDR to develop technical, social and economic benchmarks against which improvements can be assessed.

no.	activity	outputs/ milestones	completion date	comments
1.1	Select 6 locations, 4 villages with at least 10 households each and 4 larger goat farms.	Established village and household selection criteria which was used to recruit 7 villages in 3 districts (70 smallholder households) in Savannakhet province and 3 larger goat farms (in Savannakhet province).	Village selection completed on the 17-01-2020	An additional 7th village in Sepon district was selected in order to capture villages more involved in agroforestry. There was difficulty in finding appropriate larger goat farms in SVK, resulting in 1 being selected from Vientiane (VTE) province instead, however, that farm declined further involvement in the project after 2 monthly visits.
1.2	Develop and test data capturing methods to benchmark production system parameters eg (goat health production, other system components including social, economic and gender aspects)	All relevant staff have received training on CommCare data capturing software and field collection. Surveys have been developed and field-tested using CommCare software.	CommCare training completed on 23-10-19 in Vientiane. Separate training events in Armidale, Hanoi and Vientiane. Field testing completed on 22-01-20	CommCare Training provided by Dr Dave McGill Dr Alison Colvin built and pre-tested surveys in CommCare Dr Ammaly Phengvilaysouk did field-testing of the benchmarking survey in Vientiane
1.3	Measurement of key farming system parameters for 40 smallholder farms and 4 commercial farms over a 15-month period	Monthly goat survey: Monthly doe survey & Monthly kid survey	31-11-21	70 smallholders.
		Monthly household survey	14-07-22	70 smallholders and 3 ‘Large’ or commercial farms 19 months completed. Analysis in Appendix 10, 24 & 25
		1st benchmarking survey	02-02-20	Analysis in Appendix 26 & 27
		2nd benchmarking survey	31-11-21	70 smallholders. Analysis in Appendix 28
		3rd benchmarking survey	25-09-23	Analysis of project impacts on 30 farmers surveyed in June 2023 in Appendix 29, remaining farmers interviewed in September 2023 and analysis to be provided in final version of this report.
		Quarterly internal parasitology	31-07-22	Parasitology analysis in section 7.2.2
		Quarterly village environmental survey	31-11-21	7 villages, data summary in Appendix 30

1.4	Benchmarking study data analysis and interpretation (Months 12-36).	Data analyses of benchmarking surveys	1st BM 3-6-2020 2nd BM 8-03-2022 3rd BM analysis ongoing	1st BM analysis provided in Appendix 26 & 27 2nd BM analysis provided in Appendix 28 3rd BM analysis only of 30 farmers on project impacts in Appendix 29 Journal papers published in The Lao Journal of Agriculture and Forestry for 1st Benchmarking survey in 2022 Conference papers on 2nd BM survey presented in July 2022. Journal paper in progress comparing BM survey and Monthly household survey methods Journal paper on Parasitology data from Objective 1 & 2 prepared and ready for submission

PC = partner country, A = Australia

Objective 2: To assess major constraints and identify and evaluate potential solutions

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Determine importance of inbreeding depression (month 6-42)	Tissue sampling of 400 goats, DNA extraction and genotyping for parentage	30-06-22	Genotyping of 400 goats by GenomNZ using 50k SNP chip has been completed. Results have been being analysed by PhD Candidate, Sang Le and his supervisory team.
		Selection purchase and testing of GPS collars in Laos	30-03-22	10 GPS collars were tested on Lao goats at SVK University (SKU), National University of Laos (NUOL) and the Livestock Research Centre (LCR), NAFRI for up to 3 months. Results informed modification to the housing to accommodate for locally sourced batteries which are 1mm shorter. The remaining 40 GPS collars were modified and shipped to Laos for commencement of the 12-month GPS trial between July 2022 and 2023. Training of Dr Daovy Kongmanila (NUOL and Meryl Williams Fellow) on GPS data analysis was held on 5-5-22. Final GPS dataset available in August 2022 and is undergoing analysis by PhD Candidate, Sang Le and his supervisory team.
		Identification of participating farmers in GPS tracking study and training of farmers and staff	30-6-2022	GPS collars deployed on 42 goats in 14 households in 5 villages (3 goats/household, one male, one female). Monthly collection of data on SDS chip and battery replacement.

		Analysis of effective population size and inbreeding depression based on DNA tests	30-6-2023	Analysis complete by Sang van Le and supervisors. Draft scientific paper prepared.
		GPS capture and analysis of ranging behaviour and mixing on goats from 5 families in each of 2 villages	30-8-2023	Final data collection to provide 12 months of tracking data obtained. Only 16 collars remained functional throughout the whole study. Preliminary data analysis completed, but final data analysis is ongoing.
		Preparation of one or more journal papers	Ongoing	The DNA study is expected to produce two scientific papers (one prepared) and the GPS study likewise (none prepared yet)
2.2	Determine importance and causes of mortality and disease in Lao goat production systems, Identify and test control methods (months 6-42)	Development of a diagnostic field guide in Lao language	25-02-2022	A comprehensive diagnostic field guide was developed, translated to Lao language and distributed to field staff to facilitate diagnostic sample collection (Appendix 31). It was also published on the project website.
		Sample and survey collection from disease cases and controls	30-01-23	14 months of data and sample collection was completed by Mr Thaixiong Xaikhue. PhD Candidate, Preethinie Jayasekara, travelled to Laos in July 2022 and February 2023 to complete DNA extraction and shipment of samples to EMAI
		Evaluation of anthelmintic resistance using FECRT	30/07/2023	Anthelmintic resistance testing completed in 4 villages. The anthelmintics (Levamisole, Albendazole, Ivermectin) evaluated in 128 goats
		Data analysis and preparation of one or more journal papers	Ongoing	Three draft papers prepared to date and undergoing final review (Parasitology findings, Review of goat health in Laos, Causation of pinkeye". A further 2 papers are planned.
2.3	Improve forage and feeding systems in smallholder and agroforestry production systems	Staff and farmer training on goat feed and nutrition	21-07-2021	Initial training in nutrition and fodder establishment completed. Ongoing training in fodder establishment and maintenance during the project.
		Planning and review meetings	31-6-2023	Regular meetings and discussions meetings between NAFRI and PADFO/DAFO staff during field visits. Mulato, Guinea, Stylo and Paspalum identified as the key species to propagate and seeds ordered by Dr Seuth Phengsavanh
		Test of best feeding practices	30-05-2023	Feeding trials were carried out in the project villages as part of a Village Learning Activity. Testing the effects of concentrate supplementation

		Data analysis and preparation of a journal paper	Ongoing	Paper on feeding practices and growth rates of Lao goats potentially coming as part of Chanh Van Nguyen's PhD thesis

PC = partner country, A = Australia

Objective 3: To reduce market risk and increase marketing opportunities through improved understanding of the factors affecting demand and pricing of goats in Laos and Vietnam, and of the associated value chains

no.	activity	outputs/ milestones	completion date	Comments
3.1	Desktop review of international, regional and local trade in goats and goat meat	Submit report by Yr 1 month 6.	25 February 2021	01 article published in Journal of Vietnam Socio-Economic Development, ISSN 0868-359X, Vol 26, Issue 3, No 107, Oct, 2021. 01 Journal Paper submitted to the SAADC2023 and then planned to publish in the APS (see No.6 in the below item **10.2.3**. List of publications produced by objective 3)
3.2	Market surveys to ascertain past, current and likely future demand for goats and goat meat, and factors affecting pricing and demand	Design and test questionnaires, obtain ethical clearance by month 8	16 July 2021	The surveys required revisions to align with post-covid-19 conditions
		Training workshop for all relevant staff by month 12	16 December 2020	A hybrid training workshop on using CommCare was conducted in the HUAF (off-line) and connected to the UNE (online); a series of online and offline worshop were conducted within the objective 3 team.
		Conduct surveys (Consumers, Restaurant owners, Abattoirs, Traders) in first half of year 2	31 August 2022	
		Analyse data and report writing by month 24	31 August 2023	Mostly done and being considered to do more for scientific papers writing
		Journal paper(s) prepared and submitted by end of month 26	On-going	02 peer reviewed papers were published (see No.2 and No.3 in the below item **10.2.3**. List of publications produced by objective 3) 02 conference full papers were accepted and 05 conference abstracts were accepted (see No.5, No.6, No.7, No.8, No.9, No.10, and No. 11 in the below

				item **10.2.3**. List of publications produced by objective 3)
3.3	Market forecasting	Data analysis and report writing by month 30	31 August 2023	Mostly done and being considered to do more for scientific papers writing
		Journal paper(s) submitted by end of Month 34	On-going	
3.4	Characterising domestic and export value chains	Design and test questionnaires, obtain ethical clearance. Done with 3.2 by month 8	16 July 2021	The surveys required revisions to align with post-covid-19 conditions
		Training workshop in survey methodology for all relevant staff. Done with 3.2 by Month 12	16 December 2020	A hybrid training workshop on using CommCare was conducted in the HUAF (off-line) and connected to the UNE (online); a series of online and offline worshop were conducted within the objective 3 team.
		Conduct surveys Activity 3.2 targets plus 250 goat owners in 3 export and 1 domestic chain and all available traders in these chains. Surveys conducted year 2. Completed in Month 24.	31 August 2022	
		Analyse data from surveys of 800 consumers, over 100 goat restaurants, up to 50 traders and 250 farmers in 4 value chains to identify change in value along the chain, inequities, trade offs, inefficiencies and social relationships. Report submitted by month 36	31 August 2023	Mostly done and being considered to do more for scientific papers writing
		Journal paper(s) submitted by end of Month 40.	15 September 2023	1 paper was pulished (see No.4 in the below item **10.2.3**. List of publications produced by objective 3)

Objective 4: To build capacity for research and development of goat production and marketing, and initiate scaling out

no.	activity	outputs/ milestones	completion date	comments
4.1	Develop and implement Learning Alliance (LA)	5 LA meetings held over 3 years. 8 NGOs and 15 staff attended. 2 staff from Savannakhet University attended. 6 site visits held. LA members visited Natuey goat farm and 12 LA farmers visited 2 project villages. Project staff visited 3 NGO sites. Impacts of the LA were evaluated at each meeting and site visit, and at the end of the project	6-7 Feb 2020 26-27 Oct 2020 20-21 Dec 2021 30 August 2022 25 January 2023 July 2023	Membership changed over time. A total of 8 NGOs participated. Training and discussion focussed on growing/using forages, animal health, housing, breeding, markets and farmer learning methods. Meeting reports available. Evaluation methods included brief feedback sheets after meetings, group discussions after site visits, data collection on practice changes and individual staff interviews at the end of the project. Report available
4.2	Tactical capacity building	Gender and social dimensions training for 16 project and SKU staff run by Dr Lanoy Sinavong. 8 Staff trained in extension methods on the job (eg running cross visits, farmer feedback). Farmer training in planting and managing forages, disease prevention/treatment, housing, kid care, feeding pellets, blocks. Total 120 farmers	19-21 January 2021 22 July, 25 July and 11 November 2023 Late May/early June 2020 19-21 July 2023 Monthly visits	Report available Practice uptake data available in results section

4.3	Strategic capacity building	One Masters and 3 PhD students. 3 Conferences --	 2022 and 2023	See details in capacity building and communications sections.
4.4	Initiate scaling out	Village meetings held every 6 months, site visits held every month. Supplementary feeding learning day held in each village. 2 Cross visits held in two districts. 1 cross visit to Natuey farm. NGO cross visit to project village. Total 40 farmers Impacts evaluated by village data collection, and NGO interviews	July 2023 21-28 June 2023 14, 16 November 2022 16 March 2023 27 April 2023 July 2023 August 2023	 See impacts section for data on scaling out of farmer practice change.

PC = partner country, A = Australia

7 Key results and discussion

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7.1 Objective 1: Evaluate and benchmark goat production systems in Lao PDR

7.1.1 Benchmarking surveys

Full data summaries for the benchmarking surveys can be found in Appendices 26 to 29.

Smallholder farms

Smallholder goat farmers had complex farming systems with multiple enterprises conducted on small landholdings of 3.6ha on average (range 0-20ha) which increased to a mean of 4.2 ha (range 0.14-20.0ha) in the second BM survey (Figure 7.1). Fifty-seven percent of smallholders also harvested wild fish, frogs, forest fruits and nuts or insects and around 56% had no non-farm income (BM-1). The average goat herd size was 9.0 (1-37) at BM-1 and 10.2 (0-30) at BM-2. Smallholders are dependent on family labour for farming enterprises and caring for goats is shared fairly equally between adult male members (BM-1: 51/70, 73%) and adult female (BM-1: 44/70, 63%) family members. Although adult males were the main person responsible for goats. Farm capital is limited with a low annual income (BM-2: 20 million KIP/AU$1635/year, range = 500,000 KIP/AU$38 to 90 million KIP/$7046). Access to animal health services is limited with many relying on neighbours (BM-1: 67%) and family (57%) for information on goat raising. Although the presence of project staff has meant that project staff have also become an important source of information (BM-2: 94%) as have government staff (BM-2: 47%). The average number of years raising goats was 7 with a wide range from 2 years to 20 years (BM-1). All farmers raised goats to generate income (100%), 46% because they like goats, 44% because goats are easy to manage and only 30% raised goats to eat (BM-1).

Most farmers (BM-1: 64%, BM-2: 86%) depended completely on free-grazing of communal land for goat nutrition. There was a marked reduction from BM-1 to BM-2 in the number of farmers who used Graze part/Cut & Carry part management systems (33.3% and 13%, respectively). Goats graze for an average 6 hours/day (BM-1) in the wet season and 7.5 hours/day (BM-1) in the dry season. Slightly shorter grazing periods were reported in BM-2 of 5.5 hours/day in the wet season and 7.3 hours/day in the dry. Grazing is predominantly unsupervised.

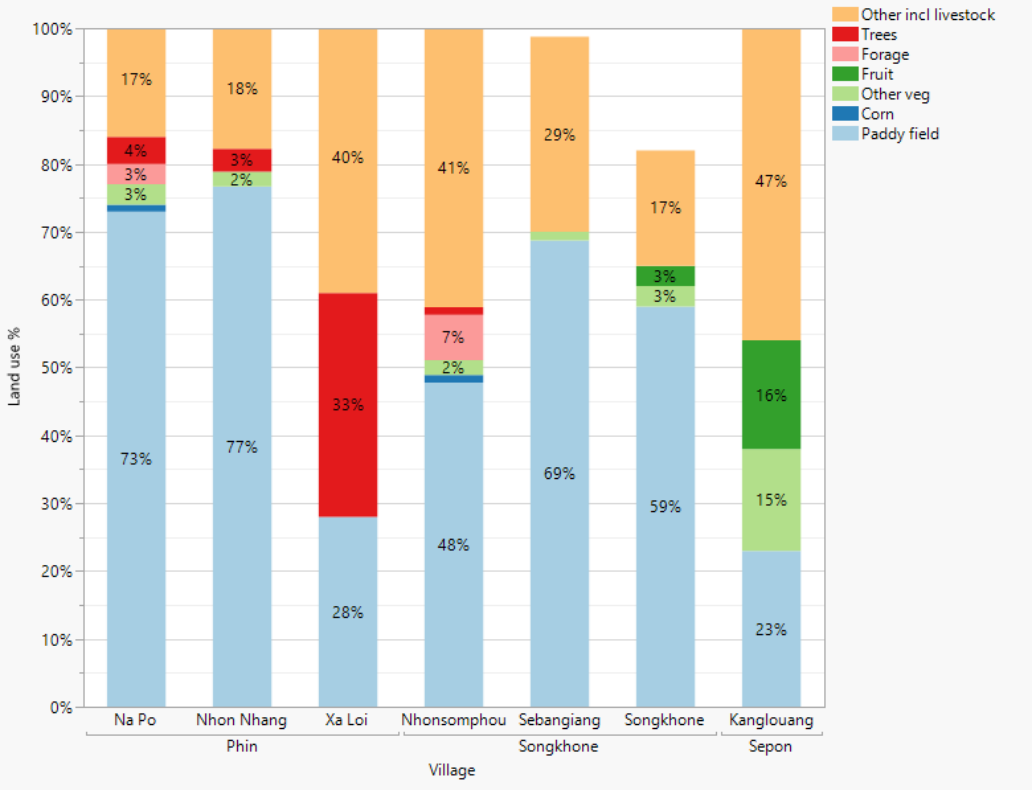

Figure 7.1: Smallholder land use a proportion of total farmland area by village, data from the 2nd benchmarking survey (n=66).

Uncontrolled breeding resulted in year-round kidding which coincided with low nutrition availability for goats in the late dry and early and late wet seasons (Figure 7.2). Increased cropping activity likely reduced grazing duration and nutrition available for goats in the late wet season. Most farmers (BM-2: 88%) reported no conflicts between raising goats and their other farming enterprises, but of those who did, goats damaging rice crops was the most common conflict (BM-2: 6/8, 75%).

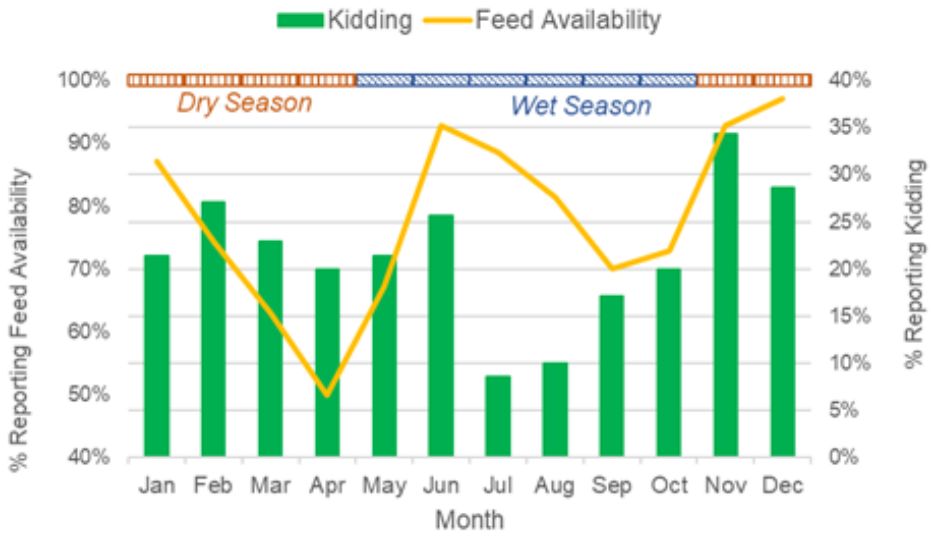

Figure 7.2: Proportion of farmers (n = 70) reporting month of kidding compared to the proportion reporting months when there were no goat feed shortages (feed availability) in Savannakhet Province, Lao PDR, data from 1st benchmarking survey.

Most farmers viewed disease as the main constraint to production, particularly facial lesions (most likely Orf; BM-2: 80%), diarrhoea (BM-2: 79%) and eye infections (BM-2: 52%). Disease management was reactive and unregulated, with 61% (BM-1) of farmers responding by opting for drugs to treat illness, and when asked how they obtained them, 74% (BM-1) purchased them themselves from stores.

BM-2 showed an increase in the goat husbandry practices of providing mineral mix, planting a dedicated forage plot for goats and keeping kids behind in the goat house after kidding (Table 7.1).

Table 7.1: Goat management practices used by smallholder goat farmers surveyed for the first benchmarking survey (BM-1, n=70) and the second benchmarking survey (BM-2, n=61).

Goat management practices used	Benchmarking survey			
	BM-1		BM-2	
	n	%	n	%
Lock up in secure house every night	68	97	52	85
Keep kids behind in goat house after kidding	47	67	48	79
Treat sick goats with drugs	42	60	35	57
Keep does behind when due to kid	45	64	39	64
Provide clean water for the goats in the goat house	48	69	22	36
Provide salt continuously to the goats	45	64	23	38
Provide housing above ground on slatted floor	43	61	13	21
Provide mineral mix	11	16	48	79
Provide concentrate feed to the goats	11	16	0	0
Dedicated forage plot	4	6	12	20
Vaccinate goats against disease	1	1	0	0
Provide special feed to goats to prepare them for market	1	1	0	0
Goat house improvements*	-	-	17	28

*New option in BM-2

Almost all farmers plan to keep raising goats in the future (BM-2: 62/66, 94%) down slightly from 100% (70/70) in BM-1. The average goat herd size that smallholders aspire to increased from 18 goats (3-100) at BM-1 to 26 (1-100 goats) at BM-2. Planned increases in goat herd numbers are a result of farmers gaining ‘good income’ provided by their goat herd (96.2%, BM-2). Full tabulation of BM-1 and BM-2 can be found in Appendices # and #.

Large farms

All large farm data presented is from BM-1. The 3 large farms had land holdings between 5 and 10 ha and an average goat herd of 47. At the time of BM-1, the large farm households had had very little experience raising goats (range 1 to 4 years). Household incomes of the large farms were higher than the average smallholder income with varying degrees of reliance on farming income (Table 7.2). Only adult males look after the goats with more reliance on hired labour on Dongdamdouane and Nateuy farms whilst Nhonsomphou large farm relied solely on family labour.

All large farms used a goat management system of part grazing and part cut & carry forage feeding which they cultivated on their own land. Grazing for Dongdamdouane was on both communal and own land, where was Nateuy and Nhonsomphou LF grazed their goats exclusively on their own land. Grazing times were higher than for smallholder goats on Nhonsomphou LF (12 h/day both wet and dry season) and Dongdamdouane (8 h/day wet season, 7 h/day dry season) but lower on Nateuy (4 h/day wet season, 7 h/day dry season).

Table 7.2: Land owned, goat herd size and income for large farms.

Village	Land owned (ha)	Goat herd size	Income from farm (KIP)	Income from farm ($AU)	Total income (KIP)	Total income ($AU)
Dongdamdouane	10	70	25,000,000	$1946	35,000,000	$2725
Nateuy	7	33	18,000,000	$1401	100,000,000	$7786
Nhonsomphou LF	5	38	40,000,000	$3114	40,000,000	$3114
Mean	7.3	47	27,600,000	$2149	58,000,000	$4516

Months of feed shortage for Dongdamdouane were February and March and for Nateuy, February, March and April. These months of feed shortages coincide with peak lactation as kidding months for the large farms occur early in the year in the dry season (December to March) with some kidding in June/July for Nateuy and July for Dongdamdouane. The large farms faced the same main constraint of goat raising as smallholders which was disease, mainly orf and diarrhoea. Goat management practices vary between large farms but all provide secure housing at night, clean water in the goat house and provide salt (Table 7.3). Whilst they all cultivate fodder on their own land, 2 have a plot dedicated to goats.

Table 7.3: Number of large farms (n = 3) using goat management practices.

Goat management practices used	Number large farms using practice
Lock up in secure house every night	3
Keep kids behind in goat house after kidding	2
Treat sick goats with drugs	1
Keep does behind when they are due to kid so they kid in or near the goat house	1
Provide clean water for the goats in the goat house	3
Provide salt continuously to the goats	3
Provide housing above the ground on a slatted floor so faeces fall through slats	2
Provide mineral block or mix to the goats	2
Provide concentrate feed to the goats	1
Have a dedicated forage plot to produce fodder for the goats	2
Vaccinate goats against disease	1
Provide special feed to goats to prepare them for market	1

All large farms in the project intend to keep raising goats in the future and with planned moderate increases to their herd of between 20-30 head. Full tabulation of BM-1 for large farms can be found in Appendix 27.

7.1.2 Monthly household surveys

Smallholder – Key productivity indicators

The average goat herd size of farmers in the MH analyses (n=51) was 12.4 (range of 4 to 40 goats) with nearly half being breeding females (47%), half being kids (48%) and less than 5% breeding males. The annual kidding rate of the project smallholder goat production systems was very high compared with the annual sales rate (Table 7.4). The pre-weaning and post-weaning mortality rates were both around 20% which equates to around 2.5 goat deaths per herd per year, although some smallholders reported very high mortality rates of

over 90%, the median mortality rates suggest this was not common. The mean sales rate of 84.6% reflects sales of around 10 goats per smallholder per year, most of which were young male goats (50%) or young females (21%), very few adult females (15%) or adult males (14%) are sold each year, most likely because males are generally sold before 12 months of age and females are kept for breeding.

Table 7.4: Key productivity indicators for smallholder goat production systems, calculated from monthly household survey.

Key Productivity Indicators	N	Mean	Median	Min	Max
Annual kidding rate (%)	45	307.0	291.9	165.5	490.9
Kids per birth	45	1.5	1.5	1.0	2.0
Annual Pre-weaning mortality <3 months of age (%)	51	17.0	13.6	0.0	93.8
Annual Post-weaning mortality >3 months of age (%)	48	20.4	18.1	0.0	96.8
Annual Sales rate	51	84.6	67.0	0.0	252.6
Annual Purchase rate	51	14.8	0.0	0.0	198.8
Annual Off-take (%)	51	69.8	56.5	-106.5	243.6

The mean sale price was generally higher for adult females (1 mil Kip/$AU79) and adult males (954,000 Kip/$AU76) with young male goats selling for around $13/head more than young females (Young males: 868,000 Kip/$AU69, young females: 704,000 Kip/$AU56). Sales occur year-round with an increase in sales during the rainy season months of May, July and August. Very few smallholders purchased goats for their herd with a median annual purchase rate of 0% (Table 7.4). Mean annual off-take was around 70% with a lower median off-take reflecting some substantial purchases by smallholders in 2 of the project villages (Appendix 10).

Large farms – Key productivity indicators

Large farm goats herd numbers were very similar to that reported in the BM-1 with fluctuations in herd size from 23 goats to 85 (Dongdamdouane: 67 head, Nateuy: 29 head, Nhonsomphou LF: 39 head) and a similar herd dynamic to smallholders with 48% breeding females, 47% kids and 4% breeding males. The annual kidding rate and kids per birth on the large farms were lower than reported by smallholder farmers. Mortality rates were lower than smallholder farms on Nateuy and Nhonsomphou-LF but Dongdamdouane had higher mortality rates (Table 7.5).

There was a similar pattern of goat sales for large farms however, monthly sales rates were generally lower with 35% of goats reported as sold in the late rainy season month of October. Although sale prices were included in the MH no data were recorded for the large farms. Purchase rates on large farms followed the same pattern as smallholders with 2 large farms not buying any goats and 1 large farm buying an average of 1 goat per year. Off take of Nateuy large farm was impressive and is likely a reflection of a good reproductive rate and low pre-weaning and post-weaning mortality. Nhonsomphou large farm had a lower off-take likely due to a lower kidding rate and low kids per birth. Dongdamdouane large farm had high pre-weaning and post-weaning mortality, more reported health syndromes (see section below ‘Annual disease prevalence’), especially lip and mouth infections (likely Orf), used half the number of interventions of other large farms (Appendix 24) had a larger goat herd (67 head) and a very low rate of sale (29.5%).

Table 7.5: Key productivity indicators for large farm goat production systems, calculated from monthly household survey.

Key Productivity Indicators	Dongdamdouane	Nateuy	Nhonsomphou LF	Mean of Large farms
Annual kidding rate (%)	178.6	200.0	148.4	175.7
Kids per birth	1.4	1.3	1.1	1.3
Annual Pre-weaning mortality <3 months of age (%)	13.9	6.4	10.4	10.2
Annual Post-weaning mortality >3 months of age (%)	32.1	0.3	0.0	0.8
Annual Sales rate	29.5	100.5	71.0	67.0
Annual Purchase rate	0	0	3.1	1.0
Annual Off-take (%)	29.5	100.5	67.9	66.0

Annual disease prevalence

Lip and mouth infections, diarrhoea and eye infections were the most prevalent disease syndromes in goats (Table 7.6). This confirms farmer concerns recorded in BM-1 that these 3 disease syndromes are significant constraints to their goat production systems. Kids aged 1 to 6 months were the age cohort that was most affected by disease syndromes overall. Disease syndromes were also prevalent in Older kids aged 6 to 12 months but less so than those aged 1 to 6 months. Kids under 1 month of age were the least likely to be affected by diseases. Diarrhoea was the most commonly reported health problem at death in all goat classes especially in grower goats and young kids still suckling (Table 7.7). Lip and mouth infection and ill thrift were the next most commonly present health problems at death but were much less common at death than diarrhoea. A summary of disease syndrome data from MH can be found in Appendix 25.

Table 7.6: Annual number of goats with disease syndrome by age/sex cohort and annual prevalence of disease syndrome over estimated total goat population of project farmers included in analysis (*n*=786), estimated kid number (*n* = 362), estimated breeding females (*n* = 373) and estimated breeding males (*n* = 50). Smallholder and large farms combined.

Disease syndrome	Annual number of goats with disease syndrome							Annual prevalence of disease syndrome (%)			
	Total cases (*n*)	Very young kids <1mth (*n*)	Young kids 1-6mth (*n*)	Older kids 6-12mth (*n*)	Total kids (*n*)	Adult females >12mth (*n*)	Adult males >12mth (*n*)	Overall (%)	Total kid (%)	Adult female (%)	Adult male (%)
Lip and mouth infections	265	21	164	43	227	24	15	33.8	62.7	6.3	29.1
Diarrhoea	175	19	93	36	149	18	9	22.3	41.0	4.8	16.8
Eye infections	120	1	78	6	85	25	10	15.3	23.5	6.7	20.1
Skin parasites	81	0	45	24	70	10	1	10.3	19.2	2.7	2.6
Coughing	40	0	8	14	22	18	0	5.1	6.0	4.8	0.0
Nasal discharge	37	0	11	16	27	10	0	4.7	7.4	2.7	0.0
Lameness/ infected foot	6	0	1	0	1	5	0	0.7	0.2	1.3	0.0
Lameness swollen joints arthritis	8	0	2	5	6	2	0	1.0	1.8	0.4	0.0
Ill thrift	8	4	4	1	8	0	0	1.0	2.2	0.0	0.0
Other health problem*	10	2	1	3	6	4	0	1.3	1.7	1.0	0.0
Bloat	8	0	1	5	6	2	0	1.0	1.6	0.5	0.0
Lumps of abscesses under skin	3	0	0	1	1	2	0	0.3	0.2	0.5	0.0
Skin wounds	1	0	0	0	0	1	0	0.1	0.0	0.2	0.0
Birth complications	0	-	-	-		0	-	0.0	-	0.0	-
Abortion	0	-	-	-		0	-	0.0	-	0.0	-

Table 7.7: Reported health problems of goats at death and proportion of total reported health problems at death within goat class (total health problems reported at death: Adult females n=18, Grower goats n=37, Young kids n=81).

Mortality reasons	Goat class					
	Adult female		Grower goats – not drinking milk		Young kids – still drinking milk	
	N	%	N	%	N	%
Diarrhoea	4	22.2%	21	56.8%	33	40.7%
Ill thrift	1	5.6%	3	8.1%	14	17.3%
Lip and mouth infection	1	5.6%	4	10.8%	13	16.0%
Goat lost	0	0.0%	0	0.0%	4	4.9%
Dog bite	2	11.1%	2	5.4%	3	3.7%
Skin parasites	0	0.0%	1	2.7%	3	3.7%
Died around parturition	2	11.1%	0	0.0%	2	2.5%
Heavy rain, cold weather	0	0.0%	0	0.0%	2	2.5%
Eye infection	2	11.1%	0	0.0%	2	2.5%
Bloat	2	11.1%	2	5.4%	1	1.2%
Kid went out with mother	0	0.0%	0	0.0%	1	1.2%
Lack of milk	0	0.0%	0	0.0%	1	1.2%
No health problem	0	0.0%	0	0.0%	1	1.2%
Fly struck umbilicus	0	0.0%	0	0.0%	1	1.2%
Dead by accident	0	0.0%	1	2.7%	0	0.0%
Discharge from nostrils	1	5.6%	0	0.0%	0	0.0%
Hit by car	0	0.0%	2	5.4%	0	0.0%
Mastitis	1	5.6%	0	0.0%	0	0.0%
Skin lumps/abscesses	1	5.6%	0	0.0%	0	0.0%
Swollen face	0	0.0%	1	2.7%	0	0.0%
Urea poisoning	1	5.6%	0	0.0%	0	0.0%

7.1.3 Monthly doe and kid surveys

Monthly doe survey

The age of registered does for the MDS was heavily skewed with most registered does under 2 years of age, the mean age was 1.7 years and the median 1.2 years (0.3 – 9.0 years). Doe bodyweights were normally distributed with a slight tail at the heavier end of the weight range; the average bodyweight over the sample period was 21.13kg (7.0 - 45.0kg) and the mean body condition score was 2.92 (1.0 – 4.0). Mean doe body condition scores remained fairly stable over the sample period (between 2.78 and 3.09) with a slight dip recorded in April 2021 (Figure 7.3). Bodyweights increased until the end of the dry season in April 2021 and remained steady until the end of the sampling period (Figure 7.3). The smaller sample size in April 2021 (due to COVID restrictions) may have contributed to the large observed fall in bodyweights and body condition scores in that month. However, bodyweights remained lower after April 2021 and body condition scores recovered to reach their highest level in November 2021. April also coincides with the end of the long dry season when feed availability is low (Figure 7.2).

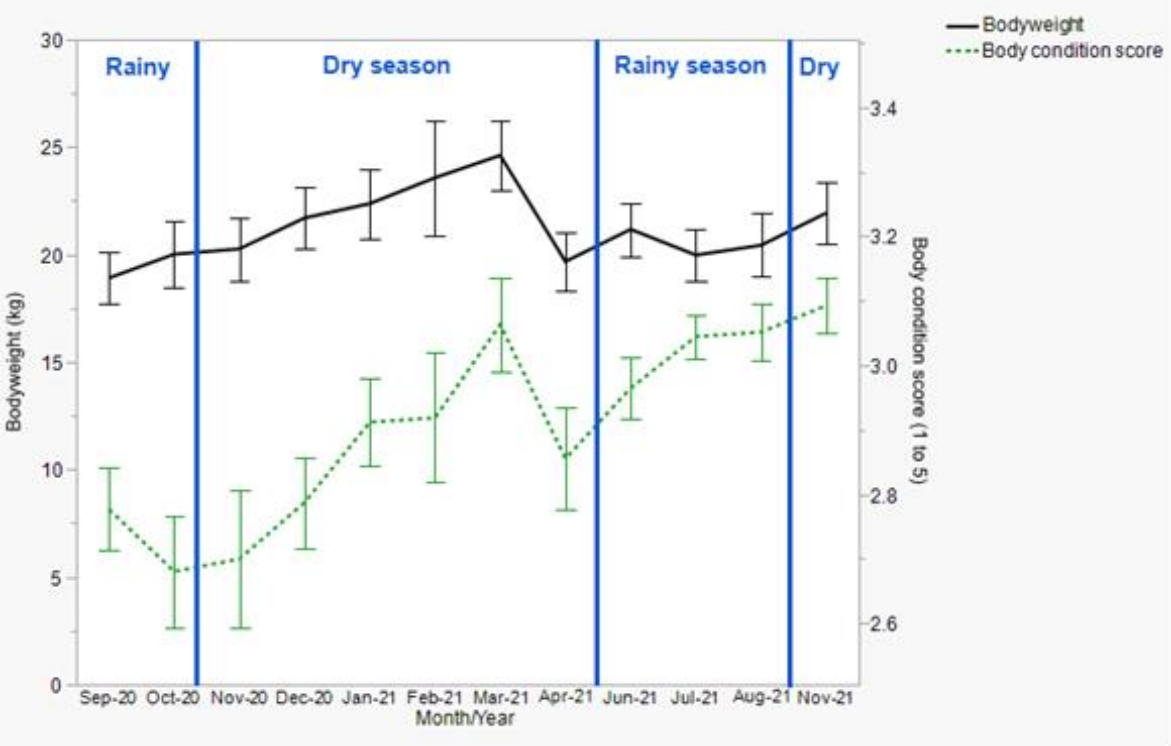

Figure 7.3: Mean bodyweight (solid line) and mean body condition score (dashed line) of native goats in Laos with 95% confidence intervals by month with rainy and dry seasons indicated.

Monthly kid survey

The mean and median age at kid registration for the monthly kid survey (MKS) was 1 month (0.02 - 5 months), the mean kid bodyweight at registration was 4.6kg (1 - 14kg) and the mean kid body condition score was 2.8 (1.5 - 3.5). The average daily weight gain of kids (ADG) increased steadily until late in the dry season (April 2021) when it fell by approximately 20g/day, mean body condition score followed the same trend but not to the same magnitude as ADG, and it remained around score 3 which is an acceptable body condition score for growing goats (Figure 7.4). The drop in ADG in April 2021 mirrored a drop of bodyweight of the does at that time (Figure 7.3), this fall in doe body weights and kid ADG is consistent with a trough in reported feed availability in April following a steady decline in feed availability from January (Figure 7.2). These coincide with the middle to end of the dry season in Lao's monsoonal weather patterns and represent a significant constraint to goat production.

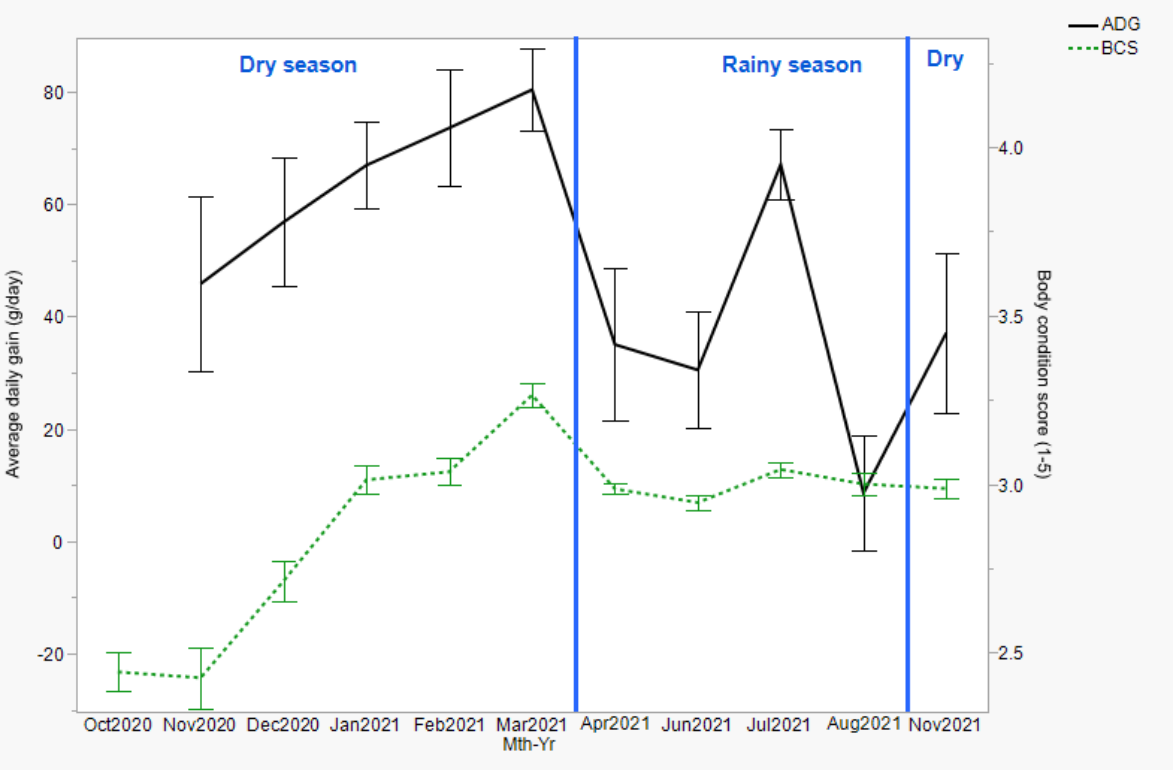

Figure 7.4: Average daily weight gain (g/day) and body condition score (score 1 to 5) of kids from October 2020 to November 2021. ADG – Average daily gain, BCS – Body condition score.

7.1.4 Quarterly village environmental surveys

A data summary of the Quarterly village environment surveys is provided in Appendix 30. There was a general trend across villages of increasing livestock numbers of goats, cattle and other livestock (mainly poultry such as ducks and chickens). Pig numbers stayed relatively stable with some villages reporting increases in pig numbers in August and November 2020, likely a recovery of pig populations after the epizootic of African Swine Fever in Asia in 2019-20. Land available for grazing mostly remained the same across villages with 1 or 2 villages reporting a decrease in land available for grazing. In most months there was no reported damage to crops by goats except in June and July 2020 when 5 and 6 villages, respectively, reported goats damaging rice, vegetable and other crops. The damage was generally quite low with most reporting less than 10% of the crop destroyed. In July 2020 there were up to 35 families in one village reporting damage to crops by goats, but in 4 months only 1-6 families reported this issue to the village leader and from Dec 2020 to November 2021, no farmers reported this problem. In all months, the village leaders reported there were no effects of goat rearing on water quality in the village.

Subjective assessments of erosion in the village environment revealed very little erosion present, most villages reported no erosion in most months (Figure 7.5 and Table 7.8). In the wet season (July 2021) and early dry season in December 2020 most villages reported less than 10% bare ground. A lot of bare ground (31-50%) was reported in all villages in the late dry season in March 2021 and in November 2021 in Na Po village, otherwise moderate areas of bare ground (11-30%) were reported in that month (Figure 7.5). Pasture and fodder availability and area of browsing trees and shrubs were both high (>50%) in the wet season month of July 2021 (Figure 6). There was also a lot of pasture/fodder and trees/shrubs available for goats in the dry season of 2020/21 (December 2020, March 2021) and the early dry season of 2021 (November).

Overall, although reported livestock numbers are increasing in the villages, the village environments are not largely affected by goat raising as there were no reported effect of goats on water quality and erosion, and bare ground was largely a result of low rainfall in the dry season.

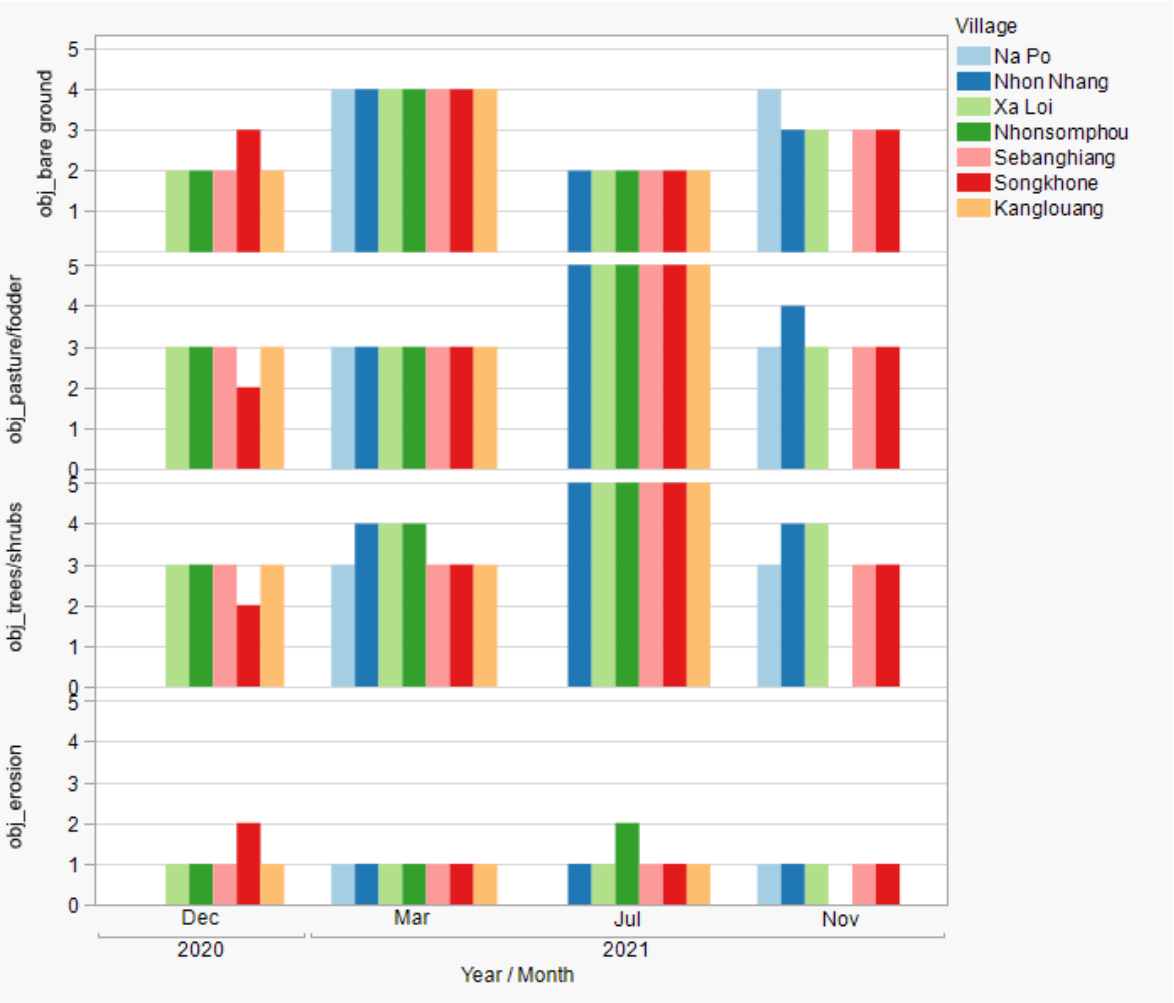

Figure 7.5: Objective assessment of bare ground (rating 1-5), pasture/fodder, browsing trees/shrubs and eroded areas by month and village (see Table 9 for definitions of ratings).

Table 7.8: Ratings for objective assessment of areas of bare ground, pasture/fodder, browsing trees/shrubs and areas of erosion.

Ratings for area of bare ground	Ratings for area of pasture/fodder	Ratings for area of browsing trees/shrubs	Ratings for areas that are eroded
1 = No bare ground	1 = No pasture/fodder	1 = No browsing trees/shrubs	1 = No erosion
2 = A little bare ground (<10%)	2 = A little pasture/fodder (< 10%)	2 = A little browsing trees/shrubs (< 10%)	2 = A little erosion (< 10%)
3 = Moderate amount of bare ground (11-30%)	3 = Moderate amount of pasture/fodder (11-30%)	3 = Moderate amount of browsing trees/shrubs (11-30%)	3 = Moderate amount of erosion (11-30%)
4 = A lot of bare ground (31-50%)	4 = A lot of pasture/fodder (31-50%)	4 = A lot of browsing trees/shrubs (31-50%)	4 = A lot of erosion (31-50%)
5 = Mostly bare ground (> 50%)	5 = Mostly pasture/fodder (> 50%)	5 = Mostly browsing trees/shrubs (> 50%)	5 = Mostly erosion (> 50%)

7.2 Objective 2: Assess major constraints and identify and evaluate potential solutions

7.2.1 Activity 2.1 Determine the importance of inbreeding depression in smallholder production systems

DNA genotyping study

The examination of inbreeding revealed low levels across the three sampling areas, as evidenced by F_{IS} values being close to zero with positive FIS values for Laos population (0.0367), Phin (0.0283) and Songkhone (0.052), while a negative value was observed for Sepon (-0.093). These data suggest that inbreeding is not a major constraint on the productivity of Lao goats. Uncontrolled breeding, free ranging grazing systems allowing intermixing between goat herds and movement of goats by sale and purchase are all likely to contribute to maintaining an effective population size and sufficient genetic mixing to limit the effects of inbreeding.

Similarly, low F_{IS} was found in Mongolian goat breeds, ranging from -0.013 to 0.025[19] and it varied from -0.014 to 0.062 in the Chinese goat breeds[20]. Those values were close to zero, indicating low levels of inbreeding in Lao natives.

With regard to the genetic origins and interrelationships of Lao goats with other goat populations, principal component analysis (PCA) of the combined Laos and reference population showed a Lao goats cluster together with Asian goat breeds (Figure 7.9). In particular, goats from China, Mongolia, Pakistan are closer to Lao goats than other Asian goat breeds.

Through admixture analysis, it becomes evident that Lao goats share a common ancestry with certain breeds from China and Pakistan. Notably, at K levels 2, 4, 6, and 9 the major blue colour cluster admixture displayed in Lao goats is also present, albeit to a lesser extent, in Guangfen (CHN_GF), Jining Grey (CHN_JN), and Luoping Yellow (CHN_LP) goats from China, as well as Teddi goats (PAK_TED) in Pakistan (Figure 7.10).

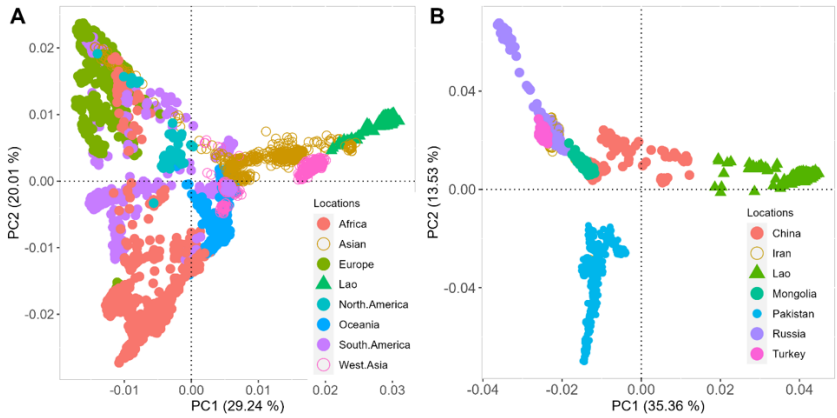

Figure 7.9: Principal component analysis for 165 Global goat breeds (A), and 43 Asian goat breeds (B).

[19] *Mukhina et al., "Genetic Diversity, Population Structure and Phylogeny of Indigenous Goats of Mongolia Revealed by SNP Genotyping."*

[20] *Berihulay et al., "Genetic diversity and population structure in multiple Chinese goat populations using a SNP panel."*

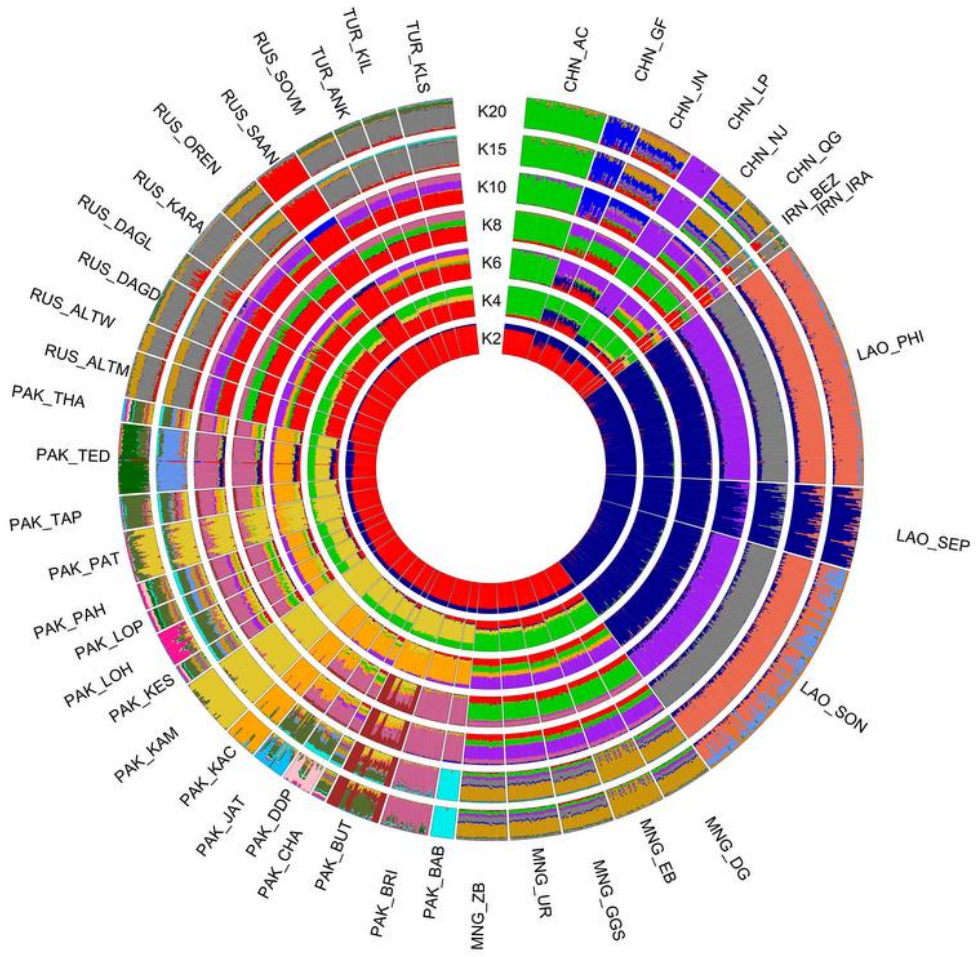

Figure 7.10: Admixture analysis of 43 goat populations in Asian regions. Results for number of clusters (K) = 2, 4, 6, 8, 10, 15 and 20 are shown. Goats are grouped by population and each individual is represented as a single vertical line. The proportion of the coloured segment in each of K represents their estimated ancestry deriving from different populations.

These findings are in accordance with prior studies. Mukhina et al. (2022) [21] observed a cluster overlap between Mongolian breeds with certain Chinese breeds, a trend similarly observed in our study. The average pairwise Fst value, denoting genetic differentiation, between Mongolian and Chinese breeds, was reported as modest, at 0.0135[22]. These authors also reported that within Asian goat breeds, Lao native goats exhibit the closest relationship with Chinese goats, as evidenced by a pairwise Fst value of less than 0.05.

The results derived from PCA analysis are consistent with those of the admixture analysis. At K = 2, a common blue admixture was observed between Lao native goat with goat from Chinese, Mongolia and Pakistani goats. At higher clusters (K = 4:8), a consistent blue admixture is observed, specifically linking Lao native goats with certain goat breeds from China and Pakistan.

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[21] Mukhina et al., "Genetic Diversity, Population Structure and Phylogeny of Indigenous Goats of Mongolia Revealed by SNP Genotyping."

[22] SV Le et al., "Genetic diversity of domestic goats from Central Laos" (paper presented at the Association for the Advancement of Animal Breeding and Genetics, 2023).

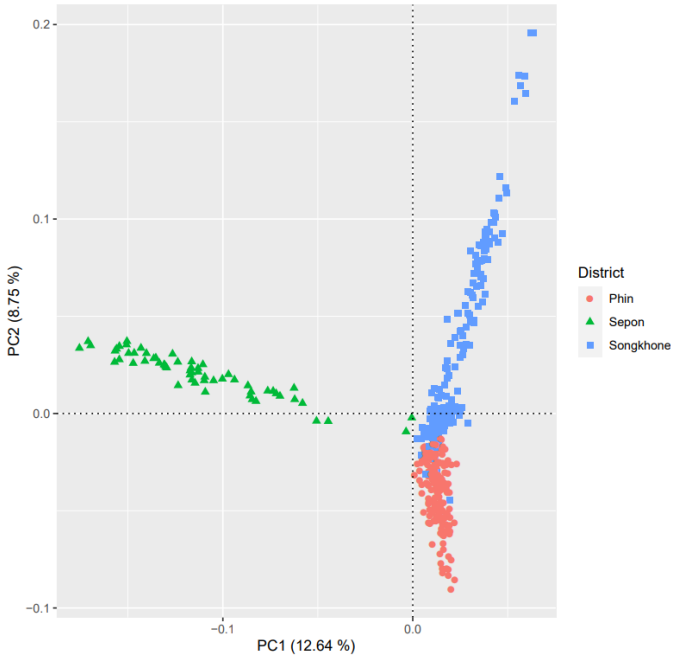

Figure 7.11: Principal component analysis for goat populations from different districts in Laos

The PCA analysis of Lao goats suggested the presence of genetic structure within Lao native goats. Goats in the Sepon districts are distinctly differentiated from those in the Phin and Songkhone districts, while there is low genetic differentiation between goats in the Phin and Songkhone districts (Figure 7.11). Analysis of genetic difference among goats from three districts in Central Laos revealed low genetic differentiation overall, but with greater differentiation between Sepon and Phin/Songkhone districts than between Phin and Songkhone. This was supported by the PCA results that showed a gene flow between goats in the Phin and Songkhone districts. Berihulay et al. (2019)[23] described that genetic differentiation between two populations could be explained by natural geographic isolation. Phin and Songkhone were not located far from each other and they both have access to the main road, known as Route 13. The farmers in these two districts were able to easily trade goats between each other's locations in Xathamua town which is located almost halfway between the two districts and is close to the Savannakhet province centre. On the other hand, Sepon is more culturally isolated, being of a more distinct ethnic and linguistic group (Mong Kong), which may reduce the trade with the other two districts.

GPS study

Data from this study are still undergoing analysis as the last data was only available in August 2023.

Durability of GPS collars: During the 12-month trial period, 16 GPS collars remained functional, showcasing their durability. However, a total of 26 GPS collars were lost or damaged over the course of the trial. Among these, 19 GPS collars encountered issues such as difficulty in connecting with satellites (15 cases) or damage to their housing and memory cards (4 cases). Additionally, 7 GPS collars were lost when the goats wearing them failed to

[23] *Berihulay et al., "Genetic diversity and population structure in multiple Chinese goat populations using a SNP panel."*

return home after grazing in the forest. It is possible that these goats were either stolen or have succumbed to various factors.

The number of months of effective operation of each GPS unit varied considerably (Figure 7.12) and the average duration of measurement when operative also reduced over time. At the beginning, each GPS recorded an average of 23.69 ± 11.74 days over 30 day-period. At the end of the trial in July 2023, the average of month GPS recording was 15.00 ± 10.64 days.

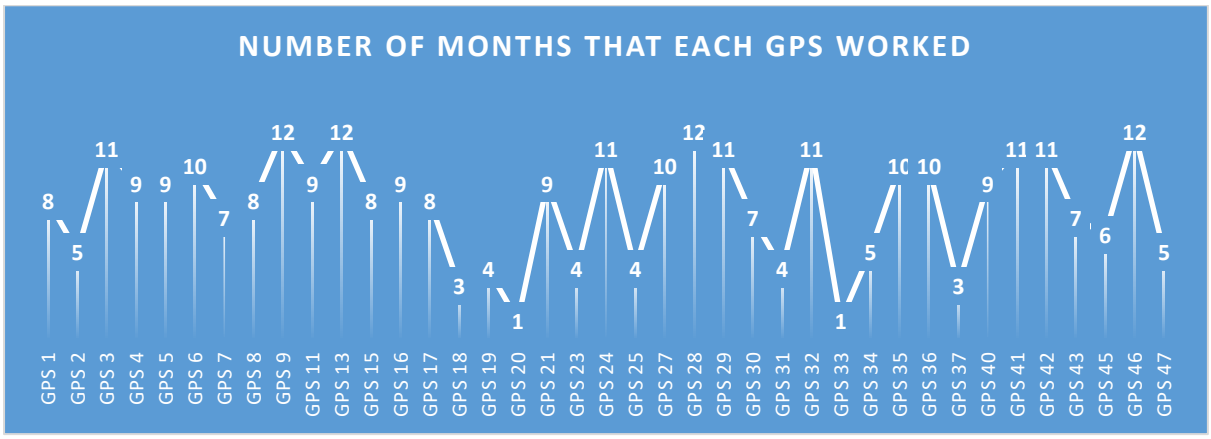

Figure 7.12: Duration of measurement for GPS collars over 12 months.

In this study, the batteries sourced locally in Laos were slightly shorter than batteries in Australia for which the GPS instrument were designed. Adjustment GPS housing was made to fit with battery in Laos but after being worn by goats for a while, some GPS devices experienced unstable connection between GPS device with satellites due to lack of power. In addition, the trial was held in Central Laos, semi-forest in tropical areas and the signal connection between GPS with satellites were unstable too. Furthermore, goats are active animals the GPS device could be damaged or the battery dislodged when fighting with other goats or impact on rocks.

Goats were most active between 7am to 7pm each day as they had an increased speed (meters/second). They were also more active during the wet season compared to the dry season, with male goats showing slightly higher activity levels than female goats within the same season (Figure 7.13).

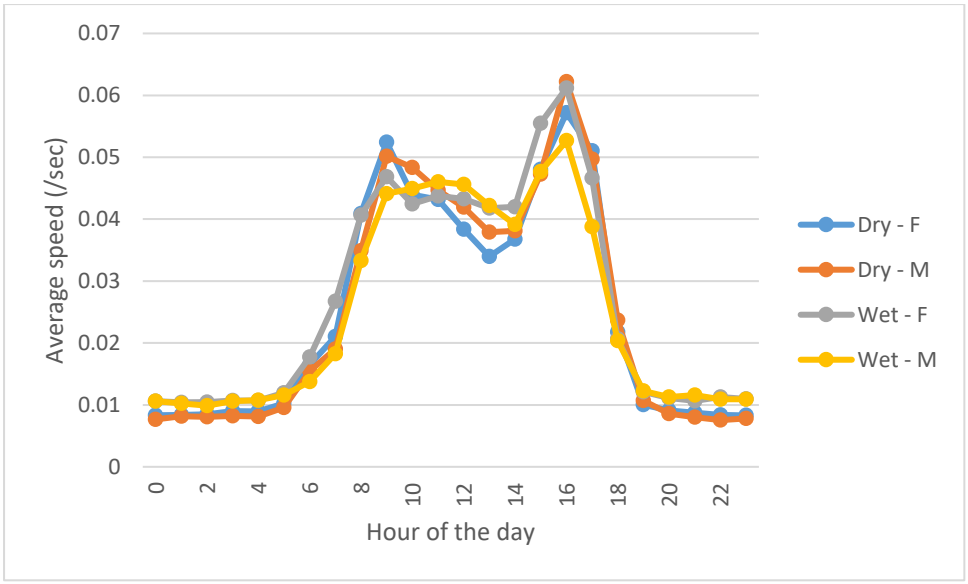

Figure 7.13: Average hourly speed (m/sec) of male and female goats in dry and wet seasons

The average daily distance travelled was 1.57 Km/day, ranging from 0.2 to 14.5 Km/day. In both seasons, male goats tended to travel further than female goats. Additionally, goats in Xa Loi and Kanglouang villages travelled greater distances compared to those in Nhon Nhang, Nhonsomphou, and Sebanghiang villages.

Home range estimates for goats in the five villages averaged 2.99 Km^2, ranging from 1.59 Km^2 to 4.90 Km^2 (Table 7.10). Home ranges of goats in the dry season season were larger than during the wet season. Female goats tended to have larger home ranges than males (Table 7.10).

Table 7.10: Home range estimate for each village in all year and in each season by gender (Km^2)

Village	All year			Wet season		Dry season	
	Overall	Male	Female	Male	Female	Male	Female
Kanglouang	2.46	1.52	2.32	1.28	2.13	1.33	1.64
Nhon Nhang	1.59	1.50	1.58	1.44	1.54	1.14	1.04
Nhonsomphou	4.90	4.76	4.58	2.12	0.34	4.60	4.49
Sebanghiang	1.70	1.30	1.66	0.30	1.42	1.29	1.60
Xa Loi	4.30	3.57	4.11	3.18	3.90	2.90	3.72
Mean	**2.99**	**2.53**	**2.85**	**1.66**	**1.87**	**2.25**	**2.50**

The home ranges size of goats in this study was 2.61 Km^2 which is smaller than reported in these other studies[24,25] likely due to the fact that these are domesticated rather than feral goats. Goats in Laos are mainly based on semi-free grazing, where they are grazing during the day and are kept in shelter at night. This restricts the extent of the range because there is a return to a common point each evening. The observation in this study that female goats have a larger range than males differs from the opposite finding in feral goats[25,26]. The somewhat larger home range in the dry season is not surprising and likely reflects additional ranging to secure food[27] but the magnitude of the seasonal difference was comparatively small.

The GPS tracking data showed that there was ample opportunity for goats from different owner flocks to mix in some (but not all) villages, although they tended to have different ranges (Figure 7.14)

[24] *Calenge, "The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals."*

[25] *Mark W Chynoweth et al., "Home range use and movement patterns of non-native feral goats in a tropical island montane dry landscape," PloS one 10, no. 3 (2015).*

[26] *Dennis King, "Home ranges of feral goats in a pastoral area in Western Australia,"* Wildlife Research *19, no. 6 (1992).*

[27] *Georgina J Yeatman and Adrian F Wayne, "Seasonal home range and habitat use of a critically endangered marsupial (Bettongia penicillata ogilbyi) inside and outside a predator-proof sanctuary," Australian Mammalogy 37, no. 2 (2015).*

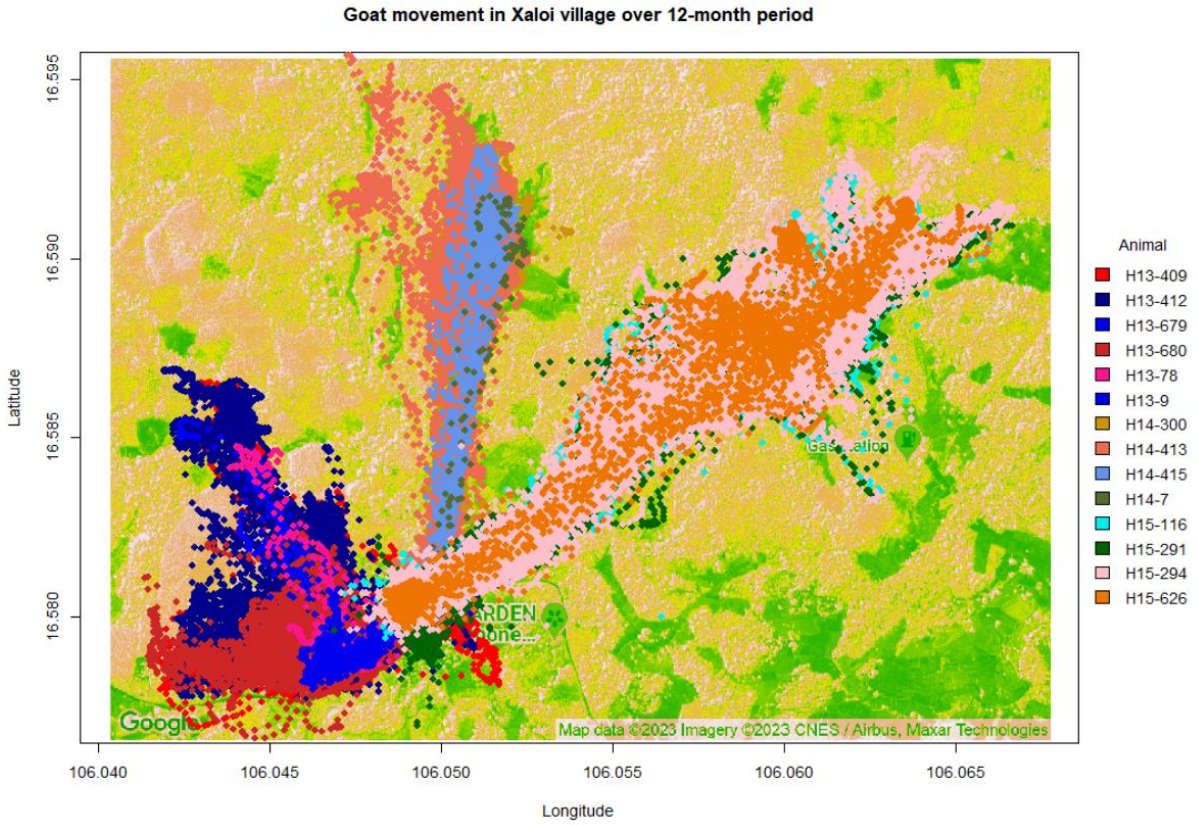

Figure 7.14: Goat movement in Xa Loi, Phin during 12-month period. Each colour dot in the plots represented an individual within 3 households (HH13-15).

At an individual animal level, the opportunity for mating across different owner herds can be visualised in the right panel of Figure 7.15 from the village of Kanglouang.

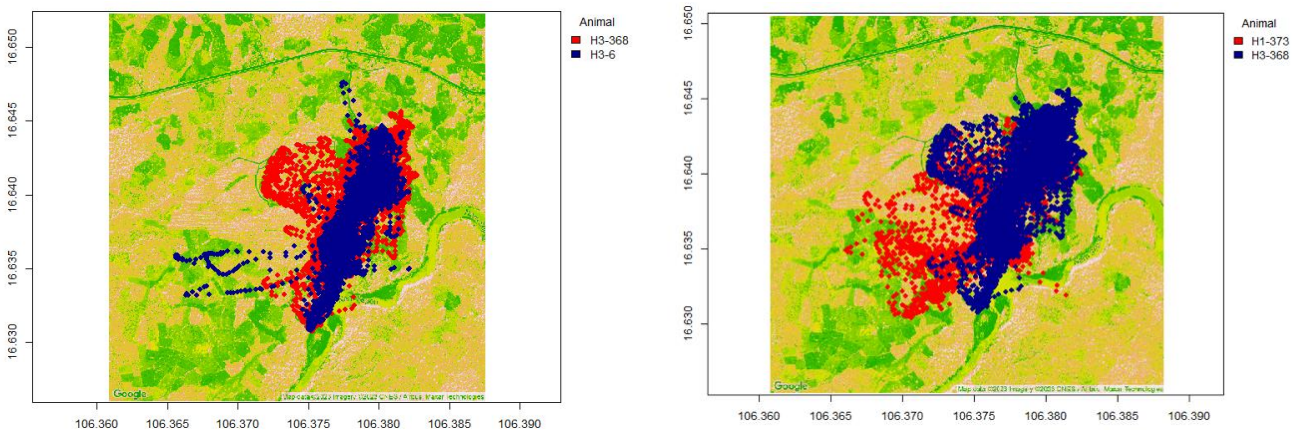

Figure 7.15: Movements of individual male and female goats in Kanglouang during 12-month period within the same family herd (left panel) or in different family herds (right panel).

7.2.2 Activity 2.2 Determine the importance and causes of mortality and disease in Lao goat production systems, identify and test control methods

Monthly field visits

Data from monthly field visits was available for 60 farms for a period of 22 months. There were 868 total visits for these 60 farms and 42.4% of visits reported with a disease incidence in farms. A high proportion of visits reported the cases of lip and facial dermatitis syndrome (12.2%), diarrhoea (9.3%), ocular and corneal inflammation syndrome (8.1%) and ill thrift (8.4%) as indicated in Table 3 (overleaf).

Internal parasites prevalence study

WEC analysis returned positive egg counts of the major gastrointestinal strongyles (*Trichostrongylus* spp., *Haemonchus* spp., *Teladorsagia* spp. and *Oesophagostamum* spp.), Nematodirus spp., coccidia (*Eimeria* spp.), *S. papillosis* and *Trichuris* spp. and tapeworm segments (*Monesia* spp.). The majority of goats had internal parasites (78.4%), 50.9% had an infection of major strongyles, 51.5% were infected with coccidia, 21.8% had *Nematodirus* spp. (Table 7.12). Most commonly goats had infections of a single types of parasite or 2 or more types of parasites (Table 7.12). Very few had polyparasitism of 4 or more types of parasites.

Table 7.12: Summary of internal parasite prevalence in Lao goats (n = 472).

Variables	n	%
Samples positive for:		
1 parasitic egg type	160	33.9%
2 parasitic egg types	137	29.0%
3 parasitic egg types	60	12.7%
4 parasitic egg types	11	2.3%
5 parasitic egg types	1	0.2%
6 parasitic egg types	1	0.2%
Samples positive for:		
Major strongyles	240	50.9%
Nematodirus spp.	103	21.8%
Trichuris spp.	9	1.9%
Strongyloides papillosis	14	3.0%
Coccidia (*Eimeria* spp.)	243	51.5%
Tapeworm segments (Moneizia spp.)	63	13.4%

The month and year of sampling had a significant effect on the prevalence of all internal parasite infections (Appendix 32). Major strongyles, *Nematodirus* spp., coccidia and tapeworm all had significantly higher prevalence in June 2022. The wet season saw significantly higher prevalence of strongyles than the dry, this was also the case for tapeworms. Higher prevalence of *Nematodirus* spp. and coccidia infections were observed in the dry season although the prevalence of coccidia was particularly high in November 2021 which is at the beginning of the dry season and end of the wet season. There was no effect of district on prevalence of the major strongyles, *Nematodirus* spp., *Trichuris* spp. or tapeworm, however, Sepon district had significantly higher prevalence of *S. papillosis* than the mean prevalence and Phin district had significantly higher prevalence of coccidia than the mean, with Songkhone and Sepon having significantly lower prevalence. Farm type had no effect on the prevalence of the internal parasites in this study. Those farmers with farm areas <2ha has significantly lower prevalence of the major strongyle and tapeworm

Table 7.11 Number of times health problems in goat households reported during a 22-month visiting period.

District	Village	No of HHs surveyed	Total visits during 22 months	No of times reported															
				Any health problem	Skin parasites	Skin wounds	Lip and facial dermatitis syndrome	Skin lumps/ abscesses	Lamness with infected foot	Lamness with swollen joints/ arthritis	Diarrhoea	Coughing	Nasal discharge	Bloat	Neurological problems	Abortion	Ill thrift	Occular and corneal inflammation syndrome	Other health problems
Songkhon	Nhonsomphou	8	114	28	2	1	1	0	2	1	8	2	2	2	1	0	9	1	0
	Songkhone	7	88	26	0	0	6	0	0	0	4	2	2	3	0	0	9	0	2
	Xebanghiang	8	98	42	1	0	13	0	2	2	6	9	2	1	0	1	10	1	3
Phin	Na Po	8	156	79	26	0	22	0	0	1	12	4	6	0	2	0	9	16	4
	Nhon Nhang	9	88	43	5	0	14	0	0	0	15	3	4	0	3	0	7	7	2
	Xa Loi	10	180	111	5	1	37	1	0	1	28	1	3	1	2	0	15	44	2
Sephon	Kanglouang	10	144	39	0	0	13	0	0	1	8	0	0	0	0	0	14	1	8
Total		**60**	868	368 (42.4%)	39 (4.5%)	2 (0.23%)	106 (12.2%)	1 (0.11%)	4 (0.46%)	6 (0.69%)	81 (9.3%)	21 (2.4%)	19 (2.2%)	7 (0.81%)	8 (0.92%)	1 (0.11%)	73 (8.4%)	70 (8.1%)	21 (2.4%)

infections. Those with 5 – 10ha had significantly higher prevalence of *S. papillosis*. There was no effect of farm area owned on the prevalence of *Nematodirus* spp., *Trichuris* spp. or coccidia.

Goat herd size had no effect on the prevalence of major strongyles, *Nematodirus* spp., *Trichuris* spp, *S. papillosis* or coccidia. Goat herd sizes between 21-30 goats had significantly higher prevalence of tapeworm than the mean. Major strongyle infections were significantly higher in grower goats (57.3%) than adult goats (46.2%) and *Nematodirus* spp. infections were significantly more prevalent in adult goats (26%) than grower goats (19%). Goat class had no significant effect on the prevalence of *Trichuris* spp., *S. papillosis*, coccidia or tapeworm. Goat management system had a significant effect on the prevalence of the major strongyle worms, *Nematodirus* spp. and *Trichuis* spp. with higher prevalence of these parasites in goats which have a combination of grazing and cut-and-carry. Conversely, those goats that were grazed all year had significantly lower prevalence of these three parasite groups. There was no effect of grazing management system on *S. papillosis*, coccidia or tapeworm. Time spent grazing in the wet season had no significant effect on the prevalence of any of the identified internal parasites. There was also little effect of time spent grazing in the dry season except for the prevalence of *Nematodirus* spp. where those grazing goats for 6-8 hours had higher than expected prevalence.

Magnitude of internal parasite infection

Mean WEC of major strongyle nematodes remained low in both grower and adult goats until June 2022 where they increased to over 500 eggs/g (Table 7.13).

Table 7.13: Mean, minimum and maximum faecal worm egg counts (eggs/g) of the major strongyles, *Nematodirus* spp., *Trichuris* spp., *Strongyloides papillosis* and mean coccidia (*Eimeria* spp.) oocyte counts (oocytes/g) for grower and adult goats by month.

			Major Strongyles		*Nematodirus* spp.		*Trichuris* spp.		*Strongyloides papillosis*		Coccidia (*Eimeria* spp.)	
Month-Year	Class	N	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Jan-21	Grower	12	100	0-300	50	0-240	5	0-60	10	0-120	65	0-300
	Adult	52	189	0-1320	133	0-1380	3	0-60	17	0-300	99	0-1140
Apr-21	Grower	47	167	0-1800	1	0-60	0	0-0	5	0-240	167	0-3780
	Adult	35	170	0-660	10	0-300	2	0-60	2	0-60	336	0-2640
Aug-21	Grower	69	139	0-1140	6	0-180	1	0-60	1	0-60	244	0-6420
	Adult	23	159	0-960	3	0-60	0	0-0	3	0-60	13	0-180
Nov-21	Grower	9	33	0-300	747	0-3900	13	0-120	0	0-0	1640	60-4620
	Adult	58	10	0-240	123	0-1500	4	0-180	1	0-60	807	0-10200
Feb-22	Grower	18	20	0-120	0	0-0	0	0-0	0	0-0	823	0-11700
	Adult	72	49	0-360	0	0-0	0	0-0	0	0-0	1415	0-13620
Jun-22	Grower	44	550	0-2520	45	0-360	0	0-0	0	0-0	1781	0-12300
	Adult	33	505	120-2760	87	0-600	0	0-0	0	0-0	695	0-3240

Using a treatment threshold of 200 eggs/g for pre-kidding and lactating does, around one third of adult goats reached the treatment threshold in January 2021 and April 2021, very few required anthelmintic treatment in November 2021 and February 2022 and nearly two-thirds required treatment in June 2022 (Figure 7.16). For grower goats the treatment threshold for major strongyles of 300 eggs/g and very few required anthelmintic treatment in January and April 2021, none in November 2021 and February 2022 until nearly half required treatment in June 2022 (Figure 7.16). Mean *Nematodirus* spp. mean WEC were relatively low with the upper range being high in some months (Table 7.13). Mean

Nematodirus spp. WEC was high in November 2021 (Table 7.13), especially in grower goats of which 44% required anthelmintic treatment in that month (Figure 7.17). Over all months mean WEC was very low for *Trichuris* spp. and *Strongyloides papillosis* (Table 7.13). Coccidia shows persistence year-round with high mean oocyte counts (OC) in grower goats in November 2021 and June 2022, and high mean OC for adults in November 2021 and February 2022 (Table 7.13). The range of OC was very large in November 2021 and February and June 2022 for both grower and adult goats.

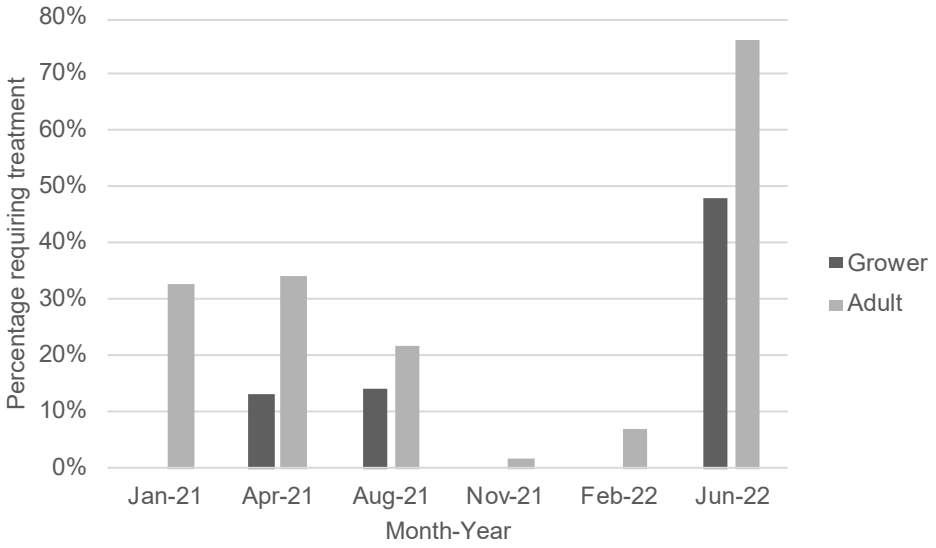

Figure 7.16: Percentage of goats requiring treatment for major strongyles based on a treatment threshold of 200 eggs/g for lactating or pre-kidding does and 300 eggs/g for grower goats.

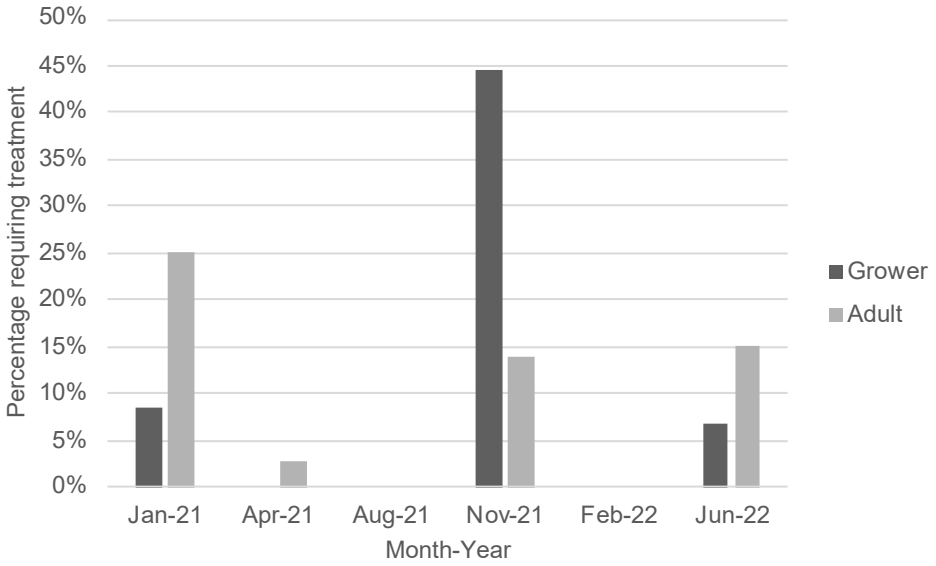

Figure 7.17: Percentage of grower and adult goats requiring anthelmintic treatment for *Nematodirus* spp. per sample period (Month-Year) based on a treatment threshold of 200 eggs/g.

Major strongyle species based on differentiation of larval cultures

In four of the five sample months *Trichostrongylus* was the most predominant nematode genus identified in larval culture Figure 7.18. *Haemonchus* made up a higher proportion of larval cultures in February and June 2022. *Oesophagostamum* also increased proportionally in February and June 2022.

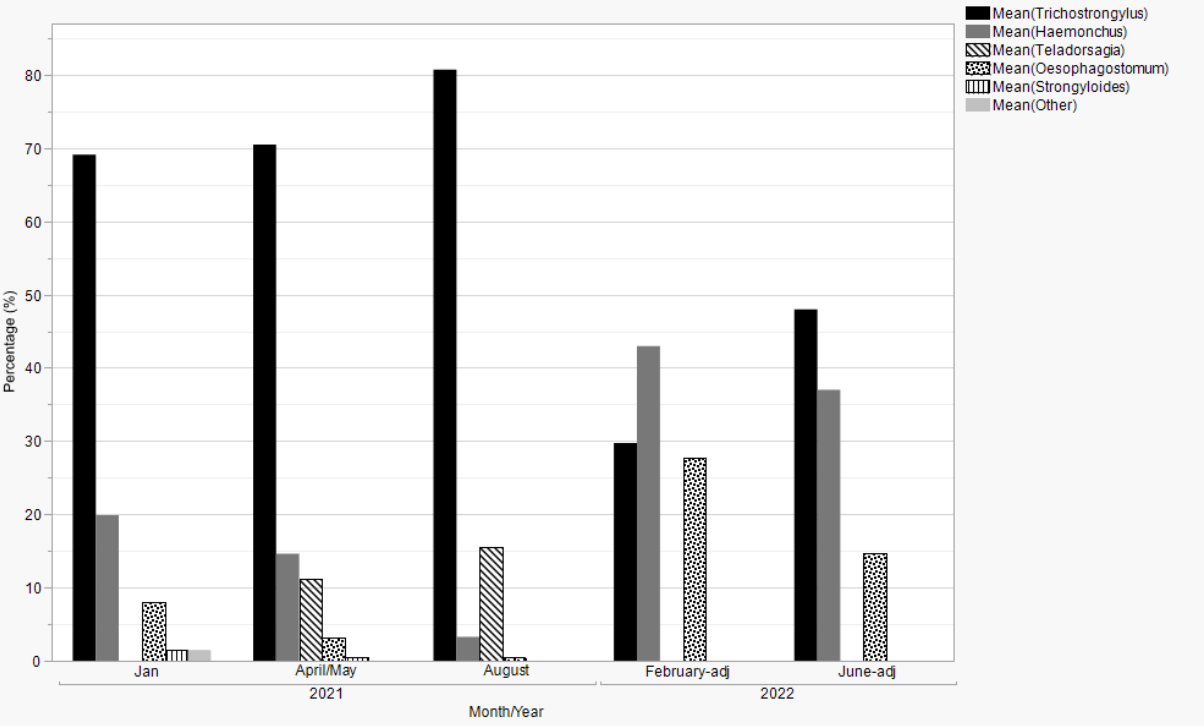

Figure 7.18: Mean percentage of genera of the major strongyle species identified through faecal larval culture.

Total worm count study

Total worm counts indicated that major nematode species of economic importance in goats were present at autopsy. All goats sampled had *Haemonchus contortus*, *Teladorsagia circumcincta*, *Trichostrongylus axei* present in the abomasum and *Trichostrongylus circumcincta* present in the small intestine (Table 7.14). Only one goat had *Oesophagostamum* spp. present in the large intestine. No Nematodirus worms were seen.

Table 7.14: Mean total counts of adult nematodes by species and juvenile nematodes by site of observation.

Site of observation	Species	Sex	N	Mean	Median	Min	Max	Species % of total count
Abomasum	*Haemonchus contortus*	Male	12	253	200	20	680	46%
		Female	12	265	230	0	720	
	Teladorsagia circumcincta	Male	12	120	50	0	400	24%
		Female	12	148	100	0	660	
	Juvenile nematode	-	12	157	110	0	680	-
	Trichostrongylus axei	Male	12	17	0	0	120	5%
		Female	12	35	10	0	160	
Small intestine	*Trichostrongylus colubriformis*	Male	12	55	40	0	240	23%
		Female	12	205	140	0	500	
Large intestine	*Oesophagostamum spp.*	Male	2	20	20	0	40	2%

Anthelmintic resistance study

There was high efficacy of albendazole and levamisole treatments with lower confidence limits (LCL) of those anthelmintics higher than the 95% threshold for emerging resistance (Table 7.15). Ivermectin also showed high efficacy against the major nematodes, however, the LCL indicate emerging resistance to that anthelmintic for all the major nematode genera, but especially *Haemonchus*.

Table 7.15: Faecal egg count reduction at Day 14 post treatment and lower confidence limit (LCL) for three anthelmintics, all villages combined.

	Anthelmintic treatment					
	Albendazole		Ivermectin		Levamisole	
Nematode species	**Mean**	**LCL**	**Mean**	**LCL**	**Mean**	**LCL**
All species	99	95	95	90	98	96
Oesophagostomum spp.	100	98	99	70	98	96
Trichostrongylus spp./*Teladorsagia* spp	99	92	94	63	98	95
Haemonchus spp.	99	95	93	55	98	96

Case control study

Eye infection syndrome

Based on probe-based quantitative real time PCR assays, the prevalence in diseased and healthy goats were for *M. conjunctivae* 94% and 74% respectively (P=0.006, OR=5.5, 95% CI: 1.46- 20.76), *Mor. ovis* (30%, 30%), *C. pecorum* (4%, 10%), *Mor. bovis* (0%, 0%) and *Mor. bovoculi* (0%, 0%) (Figure 7.19). *M. conjunctivae* was present in a high proportion of goats in both groups revealing that Lao goats are carriers of *M. conjunctivae*; however, the intensity of the infection, determined by mean genome copy number per µL of DNA extract was 67-fold higher in diseased goats than healthy goats (Figure 7.20, Table 7.16).

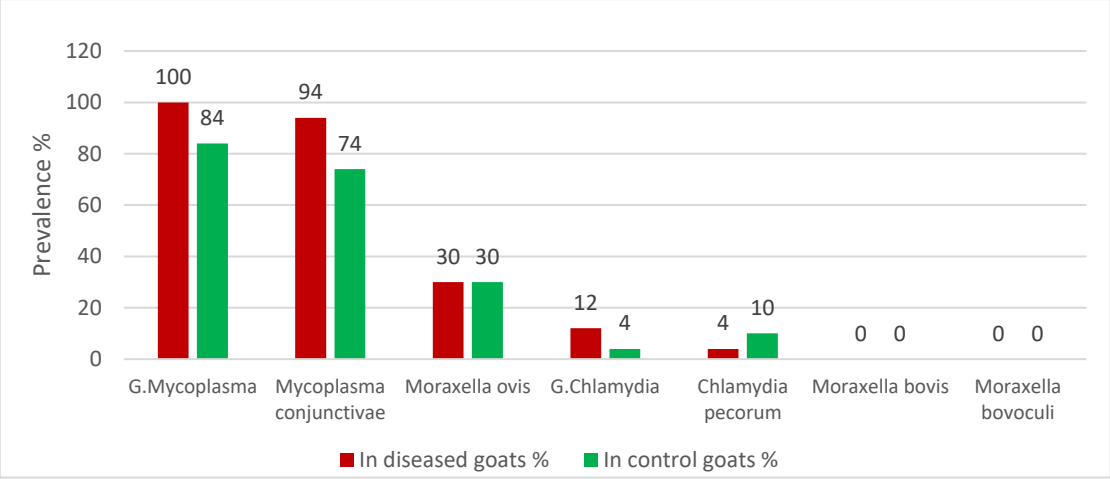

Figure 7.19: Presence of pathogens. Prevalence of different pathogens by genus and species in in eye swabs from goats with and without eye lesions.

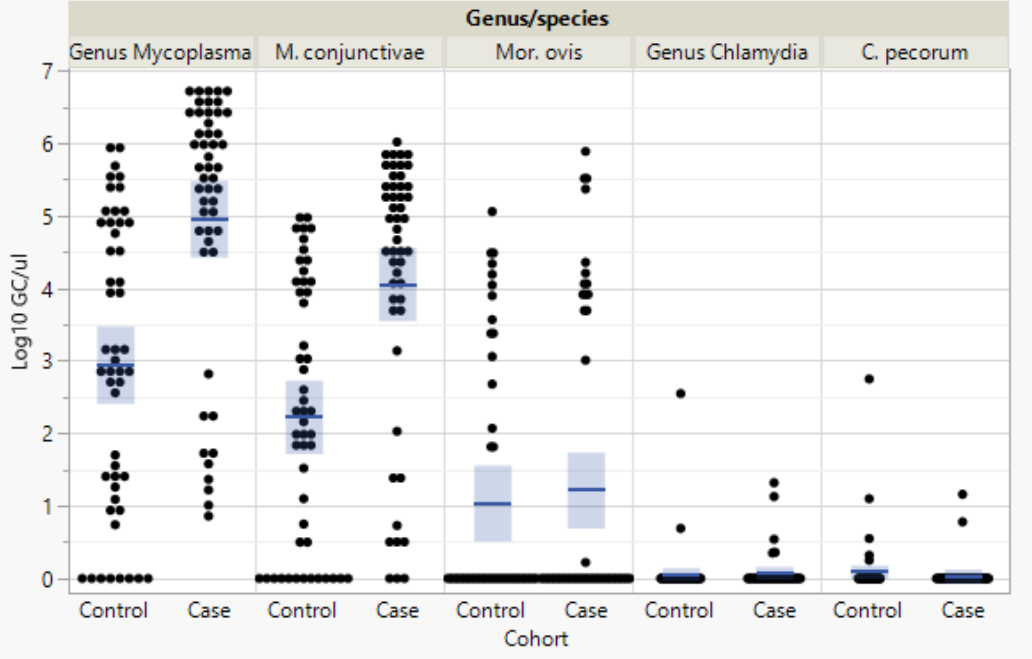

Figure 7.20: Magnitude of infection. Dot plot of log_{10} target gene copy numbers by genus and species in goats with and without eye lesions. Mean and SE included (blue line and shaded area).

Table 7.16: Mean log10 gene copy (GC) values for pathogens identified in eye swabs from goats with and without eye lesions.

Pathogen	Mean log10 of GC number		Standard error	P value
	Control	Case		
Genus Chlamydia	0.06	0.08	0.05	0.8
Genus Mycoplasma	2.95	4.96	0.27	<0.0001
Mycoplasma conjunctivae	2.23	4.06	0.25	<0.0001
Chlamydia pecorum	0.1	0.04	0.05	0.36
Moraxella ovis	1.04	1.22	0.26	0.63

M. conjunctivae is thus the likely principal causative agent of Ocular and corneal inflammation syndrome in Lao goats and the disease is commonly known as pinkeye. The causative agent *M. conjunctivae* is prevalent in both diseased and healthy groups, so it appears that Lao goats are asymptomatic carriers of *M. conjunctivae.* So, carrier status is converting to clinical infection following corneal damage or other causative factors. Dust, UV exposure, grass particles can damage the cornea. Therefore, farmers need reduce such predisposing factors of eye infection. Moreover, flies need to be controlled as they carry the infection from diseased goats to healthy goats. Further, transmission rate of pink eye can be reduced by separating diseased goats and keeping them in a shady area to prevent further eye damage. Eye drops with the antibiotic neomycin shown to be effective among project goats, thus it is recommended to continue the treatment with neomycin to Lao goats with pink eye.

Lip and facial dermatitis syndrome (scabs)

Based on SyBr PCR for *Dermatophilus congolensis* and probe-based quantitative real time PCR assays, the prevalence in diseased and healthy goats were for *Orf* 100% and 95.12% respectively (P=0.1522, OR=Infinite), *D. congolensis* (19.51%, 29.27%), *Pseudocowpox virus* (0%, 0%) and *Bovine popular stomatitis virus* (0%, 0%) (Figure 7.21). *Orf virus* was present in a high proportion of goats in both groups revealing that Lao goats are either with asymptomatic infection or contamination of control samples as the same gloves were used when sampling goats from one farm. However, the mean genome

copy number of Orf virus per µL of DNA extract was more than 32,000-fold higher in diseased goats than healthy goats (Figure 7.22). Mean log 10 of gene copy numbers for each pf the pathogen type for both controls and cases are indicated in Table 7.17.

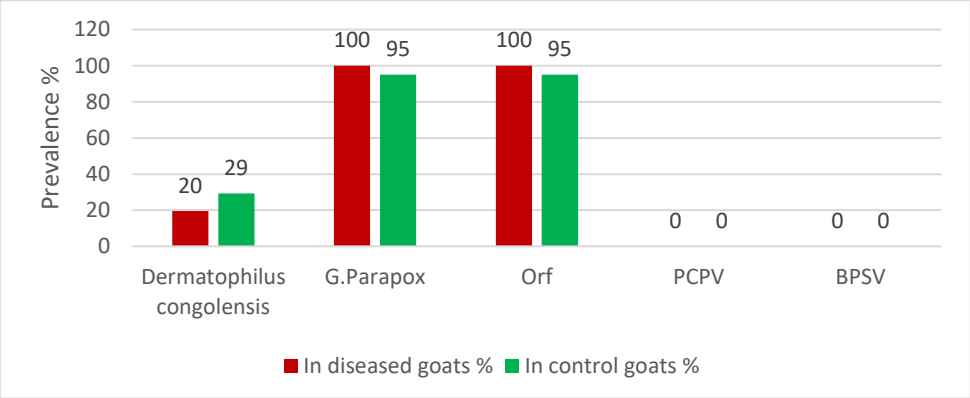

Figure 7.21: Presence of pathogens in scabs Prevalence of different pathogens by genus and species in goats with and without lip and facial scab lesions.

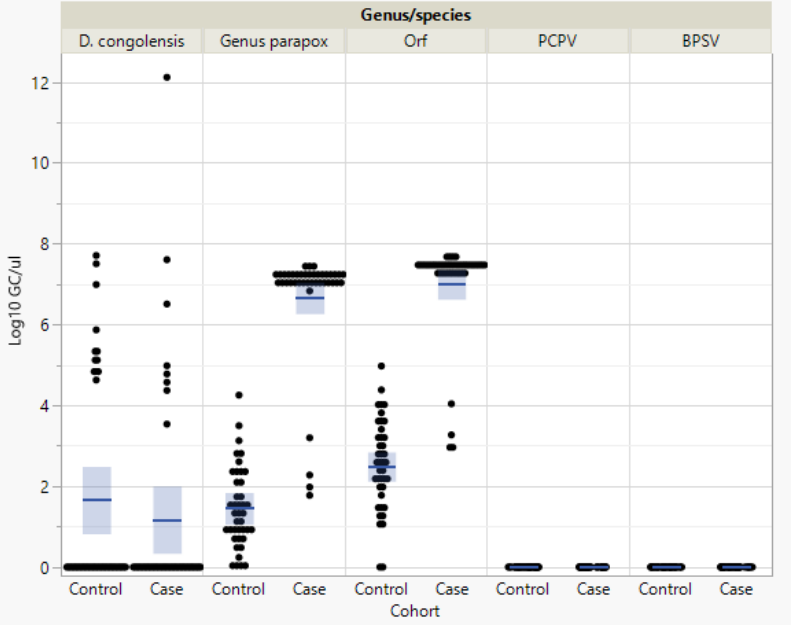

Figure 7.22: Magnitude of infection. Dot plot of log_{10} target gene copy numbers by genus and species in scab material or skin scrapings from goats with and without scabby lip and face lesions. Mean and SE included (blue line and shaded area)

Table 7.17: Mean log10 gene copy values for pathogens identified from cab material or skin scrapings from goats with or without scabby lip and face lesions.

Pathogen	Mean log10 of GC number		Standard error	P value
	Control	Case		
D. congolensis	1.66	1.18	0.42	0.42
Genus Parapox	1.46	6.66	0.2	<0.0001
Orf virus	2.49	7.00	0.18	<0.0001
PCPV	0	0	0	-
BPSV	0	0	0	-

Orf is thus the likely principal causative agent of lip and facial dermatitis syndrome in Lao goats and the disease is commonly known as scabby mouth. The causative agent *Orf* is prevalent in both diseased and healthy groups, due to the contamination of the control sample as not changing gloves during sampling between goats from same farm. However, gloves were changed when sampling between different farms. The issue of contamination of the control sample is further suggested by presence of higher folds of gene copy number of Orf virus in samples from diseased goats compared to control group. Intramuscular penicillin/streptomycin injections together with disinfectant sprays were used on diseased goats. An autogenous vaccine can be prepared with the scabs from clinically infected goats as a treatment and preventive, but this was not attempted during the project.

Respiratory disease syndrome (nasal swabs)

Based on probe-based quantitative real time PCR assays, the prevalence in diseased and healthy goats were for *Mycoplasma ovipneumoniae* 94% and 76% respectively (P=0.012, OR=4.95, 95% CI: 1.3- 18.81), *Mannheimia haemolytica* (60%, 52%), *P. multocida* (0%, 2%), *M. capricolum capripneumoniae* (0%, 0%), Bovine respiratory syncytial virus (0%, 0%) and Bovine parainfluenza 3 virus (0%, 0%) (Figure 7.23). *M. ovipneumoniae* was present in a high proportion of goats in both groups revealing that Lao goats are carriers of *M. ovipneumoniae*. With regard to the magnitude of infection (Figure 7.24, Table 7.18) there was a significantly greater number of *M. ovipneumoniae* gene copies in the diseased group than the healthy group representing an up to 30-fold higher level of organisms in the diseased group.

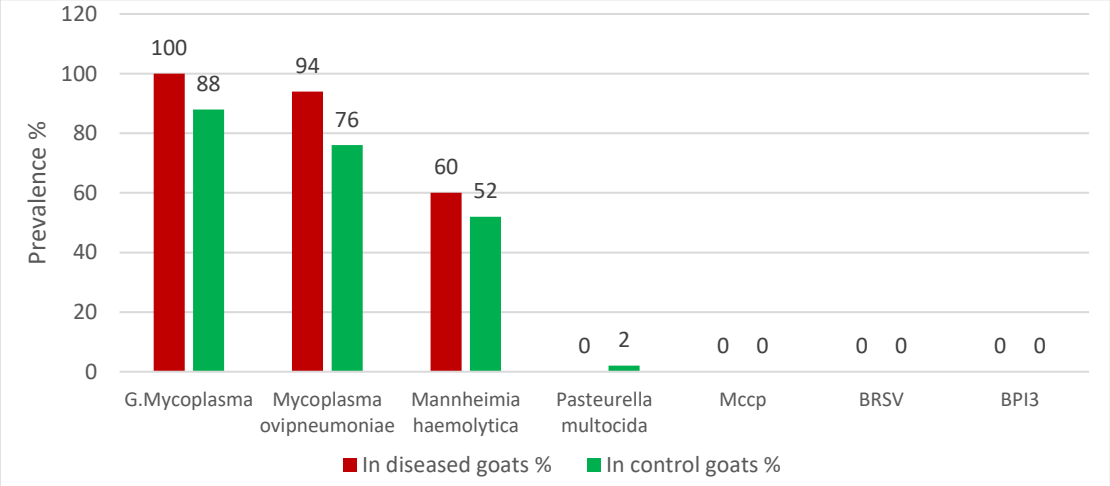

Figure 7.23: Presence of pathogens in nasal swabs Prevalence of different pathogens by genus and species in goats with and without signs of respiratory disease.

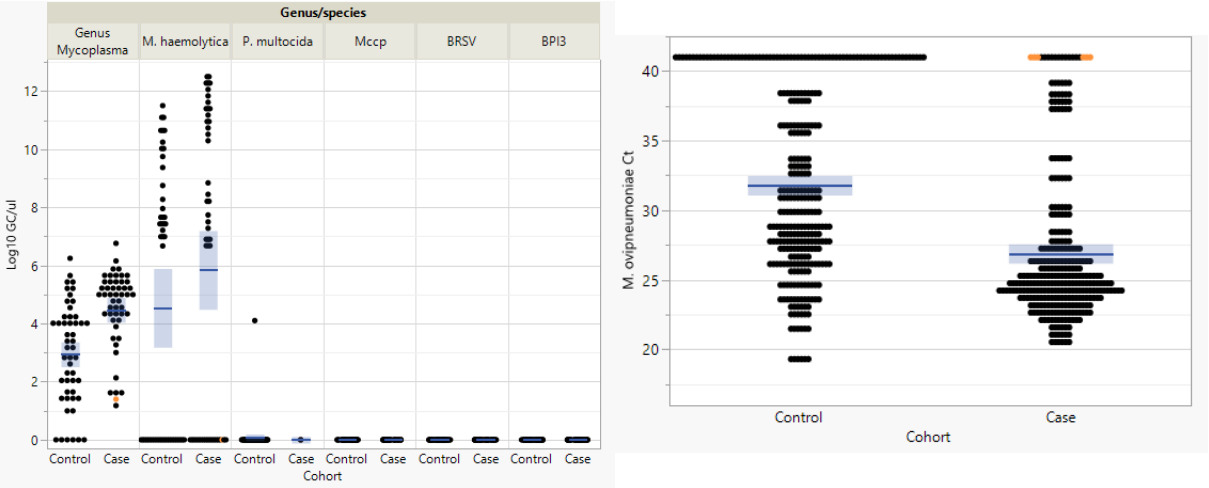

Figure 7.24: Magnitude of infection detected in nasal swabs. Dot plot of log_{10} target gene copy numbers by genus and target gene copy numbers (left panel) and cycle threshold (ct) values for *Mycoplasma ovipneumoniae* (right panel) in nasal swabs from goats with and without signs of respiratory infection. Mean and SE included (blue line and shaded area). Note. Lower ct values indicate greater numbers of gene copies. Each unit of ct difference represents approximately a 2-fold difference in gene copies.

Table 7.18: Mean log10 gene copy (GC) values for pathogens identified from in nasal swabs from goats with and without signs of respiratory infection.

Pathogen	Mean log10 of GC number		Standard error	P value
	Control	Case		
Genus Mycoplasma	2.95	4.48	0.22	<0.0001
Mycoplasma ovipneumoniae	31.8*	26.9*	0.88*	0.0002
Mycoplasma. capricolum	0	0	0	-
BPI3	0	0	0	-
BRSV	0	0	0	-
Mannheimia haemolytica	4.54	5.85	0.68	0.18
Pasteurella multocida	0.08	0	0.06	0.32

* Based on ct values rather than gene copies as no standard curve was available for this bacterium. Lower ct values indicate greater numbers of gene copies. Each unit of ct difference represents approximately a 2-fold difference in gene copies.

Based on these findings *M. ovipneumoniae* is the likely most common causative agent of respiratory syndrome in Lao goats and the disease it causes is commonly known as atypical non-progressive pneumoniae. The causative agent *M. ovipneumoniae* was prevalent in both diseased and healthy groups, so it appears that Lao goats are asymptomatic carriers of *M. ovipneumoniae.* The reason for asymptomatic carrier stage is still unclear but it is reported that the disease could be due to the involvement of some other factors. Such factors include, stress, higher temperature and lower humidity, over-crowding and low ventilation. Such conditions are present when goats are housed under crowded unhygienic conditions. Studies have shown that fluoroquinolones, tetracyclines and macrolides are effective against *M. ovipneumoniae.* The project has already implemented the treatment with deep intramuscular oxytetracycline, thus recommended to continue the same treatment to Lao goats with respiratory syndrome.

7.2.3 Activity 2.3 Determine the importance and causes of mortality and disease in Lao goat production systems, identify and test control methods

Forage establishment

Working with SKU by establishing multiplication forage plot of 4 varieties (Guinea, Mulato, Stylo and Paspalum) in university that allowed students learn and practice on forage agronomy. During the project there were about 12 students that wrote theses on forage management. Apart from this, it has been a source of cuttings for farmers, with 6 full ute loads of cuttings utilized during the project.

In addition to supplying he seeds of Guinea, Mulato, Stylo and Paspalum were supplied to 2 big goat farms. Then the farms continued to expand the area by using their own planting materials.

Champion farmers in forage and feeding improvement. There were 22 farmers who emerged as the best adopters of forages and these were selected for improving feeding trials involving supplementation.

Overall 90-95% of the forage area developed was developed using seed, with cuttings and vegetative propagation accounting for 5-10%. Seed propagation was far easier than vegetative.

We found that in some project target areas forage planting progressed faster due to goats being an important source of family income and farmers thus are more receptive to ways to improve goat productivity through using better and easily access feed.

However, in other areas the forage is not an option for every farmer as the natural feed is still available, there were also other problems such as labour shortage in the family to look after forage planting and building the fence around plots to keep other stock of the plots.

Farmers mainly use forages in cut and carry systems and only few farmers occasionally let the goats graze on the forage plots.

In the dry season there is still limited availability of forages due to all of them dry out, particularly in the middle of the dry season when there is very little or no rainfall at all.

Apart from those problems, there are also some technical problems such as low germination rate of seed and weeds that caused some farmers to stop planting.

However, farmers have started to come asking for the forage seeds is a good sign for more adoption in next coming years

Mineral block distribution

Between April 2021 and end of June 2023 1,423 blocks were supplied to 68 project families in 7 villages and 435 blocks were supplied to 65 non-project families as shown in Figure 7.25. Farmers showed strong willingness to pay 50% of the cost of blocks, but willingness to pay 100% was not tested. The mineral blocks named ‘Mineral Block KS97’, were made in Thailand and cost approximately 30,000kip/block. The rate of feeding mineral blocks to goats was 2 blocks per 10 goats every 2 months.

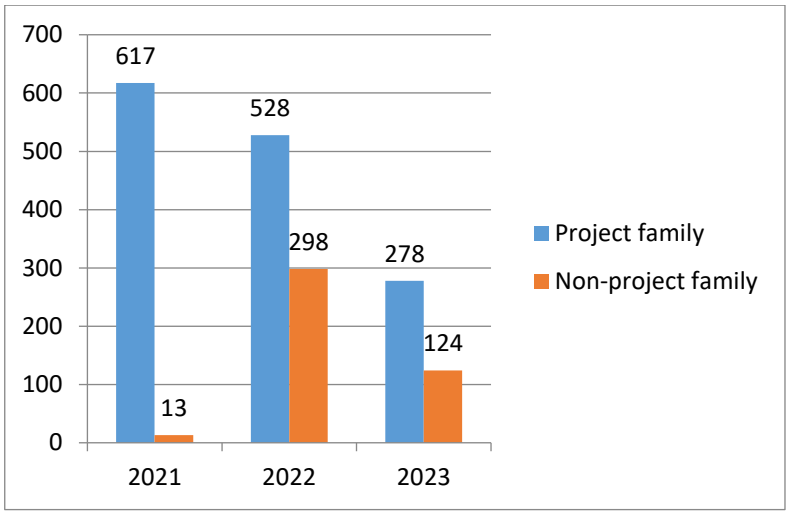

Figure 7.25: Numbers of mineral blocks distributed by year to project and non-project household.

Nutrition trials - village learning activities

Grower goat feeding trial

Bodyweights of the 2 treatment groups were similar at the start of the trial in December 2022 (Figure 7.26). Bodyweights and ADG of grower goats fed concentrate feed were higher than control grower goats that had not been fed concentrate feed (Figure 7.26).

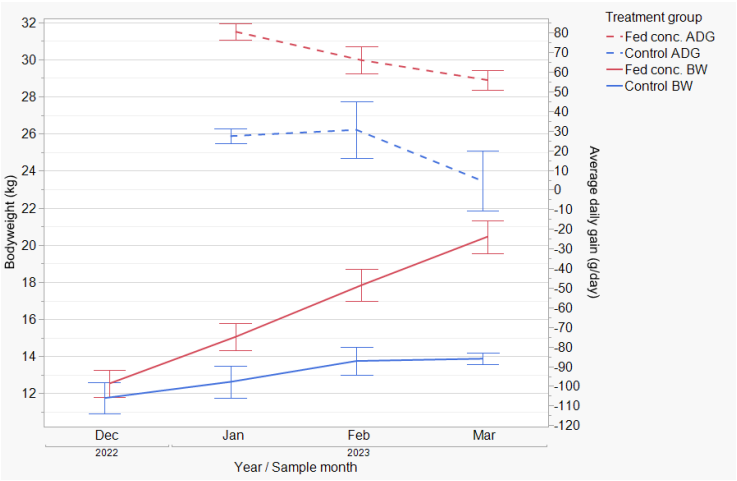

Figure 7.26: Bodyweights (BW, kg) and average daily gain (ADG, g/day) of grower goats fed concentrate feed (100g/goat/day) and control group (0g/goat/day).

Results were encouraging with supplemented goats putting on over 7.9 kg of weight over the 4-month period (mean ADG of 67.5) while the few control goats grew much more slowly gaining just over 2.1 kg in the same period (ADG = 20.8 g/d, Table 7.19) Body condition score (BCS) remained relatively stable throughout the treatment period (range 2.7-3.2) with those on concentrate feed recording higher BCS than control goats. However, their BCS were also higher at the start of the trial. There was less variation of BCS among fed grower goats than control grower goats. Unfortunately, due to the small number of control goats, the results need to be interpreted with caution.

Table 7.19: Bodyweights and average daily gain of grower goats fed 100g/goat/day for a four-month period (December 2022 to March 2022) and control goats (0g/goat/day).

		Treatment group	
		Control	Fed concentrate
	N	4	31
Initial Bodyweight (kg)	Mean	11.8	12.5
	Min	10	6
	Max	14	25
Final bodyweight (kg)	Mean	13.9	20.5
	Min	13.0	14.0
	Max	14.5	37
Total weight gain (kg)	Mean	2.1	7.9
	Min	0.5	4.5
	Max	3.0	13.0
Average daily gain (g/day)	Mean	20.8	67.5
	Min	-28.6	16.1
	Max	69.4	210.5

Doe feeding trial

The available data from the doe trial does not account for births so it is difficult to make clear inferences from it.

The bodyweights of the supplemented goats were 4 kg lower on average than the control goats at the initial measurement in December (Figure 7.27). Low numbers of control goats mean large standard errors for that group. ADG declined for both treatment groups across the trial period, but supplemented does generally exhibited higher ADG than control group does. The trial was conducted during the middle to late dry season, this, combined with births, may have contributed to the drop off in body weights and ADG in March 2023. Mean BCS of fed does were similar to BCS of control does at the beginning of the trial. Whilst BCS of control does remained stable, the BCS of fed does increased to an average score of 3.4 in January, after which is declined to 3.05 in March but remained higher than the control group BCS.

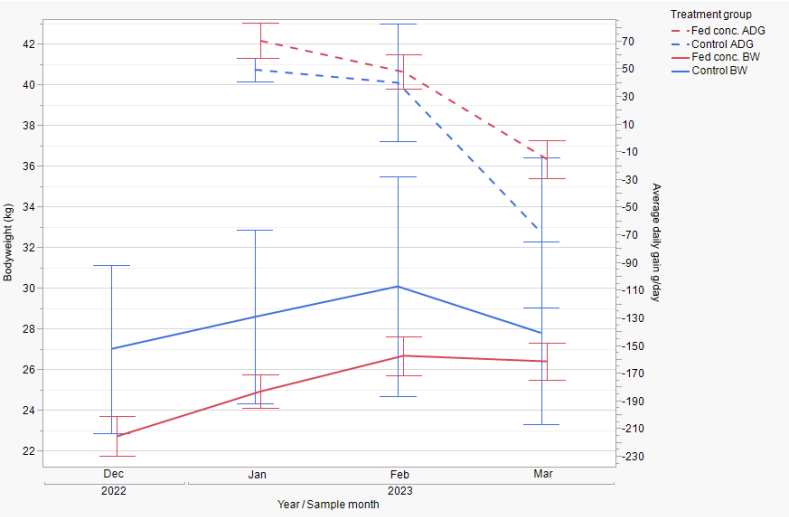

Figure 7.27: Bodyweights (BW, kg) and average daily gain (ADG, g/day) of pregnant does fed concentrate feed (100g/goat/day) and control group (0g/goat/day).

Urolithiasis trial

The results showed that the incidence of urolithiasis determined by ultrasound was 12.2% before starting the experiment, supporting the notion that this is a widespread phenomenon. Those animals were excluded from the experiment. Two further cases of urolithiasis were detected by clinical signs (one was in treatment 5 on Day 11, and the other was in treatment 6 on Day 14 of the experiment). Ca supplementation had no effect on fecal P (0.86 g/100 g fresh weight), pellet intake (752 g DM/day), water intake (2.22 L/day), or liveweight gain (170 g/day). Urine pH index (mean urine pH (Day 7 + 14)/Urine pH Day 0) tended to increase at the highest level of Ca supplementation (Urine pH index, from low to highest Ca treatment: 0.94^{a}, 0.99^{ab}, 1.00^{ab}, 0.96^{ab}, 1.01^{ab}, 1.13^{b}).

All treatments resulted in a lower than normal serum calcium levels and higher than normal serum phosphate levels, which should range from 4.2 to 9.1 mg/dL. It appears that high-phosphorus diets may negatively affect kidney function, resulting in a decrease in vitamin D synthesis. The decline in vitamin D levels may result in a drop in blood calcium and an increase in blood phosphate levels due to impaired renal excretion. Urinary fractional excretion of Ca was slightly less than 1% which is considered to be low, and may indicate that the kidneys are conserving calcium. Despite common advice to supplement goats with Ca to reduce the risk of urolithiasis, there was no evidence that it does it by increasing fecal P. Ca supplementation at high levels could even exacerbate the risk of urolithiasis if it increases urine pH.

7.3 Objective 3

Below is a summary of the main findings, details of the data can be found in Appendix 33 to 37.

7.3.1 Desktop review of international, regional and local trade in goats and goat meat

The studies conducted as part of Objective 3 found that the continued growth of goat consumption in Vietnam is driven by: 1) large and growing population (97.3 million) and economy, 2) high meat consumption relative to Gross Domestic Product; 3) high social value placed on goat consumption; 4) increasing popularity of meat consumption; 5) established socio-cultural goat consumption practices; 6) increasing preference for grass-fed meat; and 7) increasing supply from neighbouring countries. As a result, growth in Vietnamese goat meat prices has continually outperformed growth in goat supply over the past decade. Goat and goat meat supply is mainly produced by thousands of smallholder farmers in Vietnam and neighbouring Laos and Thailand. Hence, there are important livelihood and rural development opportunities for producers to increase their goat production. This is specially the case for Lao smallholders, as each additional goat sold represents a 4.75% increase in the household income per year. To reduce risks to goat producers, research is needed to: 1) forecast the current and future demand for goats in Vietnam to prevent oversupply leading to price collapse, 2) understand how premiums are awarded for goat characteristics; 3) investigate pathways for formalising trade and its impacts on smallholders; and 4) establish strategies for producers to improve supply without degrading natural resources, or increase disease outbreak risk.

7.3.2 Market surveys to ascertain past, current and likely future demand for goats and goat meat, and factors affecting pricing and demand

The Mountain Goat Value Chain in Laos and Vietnam is a growing-industry due to goats being appropriate for smallholder conditions and resources, buoyant markets and scope for price premium incentives for high quality goats. Goat is a highly desired meat in the region. Price of goat meat is considerably higher than beef price. Prices paid per goat increase dramatically as we move downstream in the value chain in Laos and Vietnam; however, the increase is bigger in Vietnam than in Laos. The price differentials between

countries represents an opportunity for smallholder farmers in Laos to export their goats to Vietnam. However, informality and lack of contract farming, road infrastructure in Laos with several issues and trade restrictions to export goats to Vietnam have constraint the development of this industry.

Approximately, two thirds of Vietnamese goat consumers are uncertain if they have consumed mountain goat due to the lack of certification and traceability. In contrast in Laos, goat consumers are more certain about the type of goat they have been eating due to the goat availability within their region.

Most of consumers (91.9%) preferred to enjoy goat meat at the restaurants with the most consuming frequency being once or a few times per month (40.9%). In comparison, only 40.5% of them had an interest of consuming goat meat at home (including self-cooking at home and taking goat meals from restaurants). Though goat meat price was reviewed as more expensive than other types of meat, it was listed as the most preferred meat. Consumers (65.6%) only cared a little about the origin of the goats. Instead, the values of goat meat were evaluated by the dishes or the meals that the goat meat was properly prepared and/or cooked. The results showed that steamed (78.1%) and roasted (60.3%) goat meals were the most preferred dishes reported by the Goat Meat Consumers, and some differences in consumer preference among provinces.

Among Vietnamese goat meat consumers, the socio-demographic characteristic "*monthly income*" is the most robust and relevant factor that impacts on the willingness-to-pay for Laos goat and mountain goat meat and it is also the leading indicator of future goat demand. One of the most interesting and perhaps unexpected findings is that women are more willing to pay and extra premium price for Lao Goat (mountain goat) than men. This result is in line with the literature that indicates women care more about healthy food than men. In addition, consumers who value the "*health benefits*" of goat meat will agree to pay more, being the second factor that has a significant impact on the willingness to pay price premiums. Moreover, in contradiction with assumed understanding, "*good taste*" does not affect the premiums paid for Laos/mountain goat. An interesting finding is the "*relax motive*" is the significant factor in the goat meat consumption. This implies the entertainment purpose would be one of the key points consumers focus when choosing a restaurant. The variable "*location*" (urban - rural) does not affect the willingness to pay premiums for Laos goat. Similarly, other socio-demographic variables such as "*age*", "*marriage*" and "*number of family members*" are insignificant. Besides "*good taste*", the other food motives familiarity, availability, price, natural ingredients are insignificant. Finally, "*animal welfare*" is a food motive that appears as a highly negative significant factor that reduces the willingness to pay price premiums for Lao mountain goat meat.

In the case of consumers in Laos, *"monthly income"* is also the most relevant factor that influences the willingness-to-pay premiums for mountain goat meat. In contrast to Vietnamese consumers, location is the second most important factor and there is a big gap between urban and rural areas regarding the willingness to pay for mountain goat among Laotian consumers.

7.3.3 Market Forecasting

The average income per capita in Vietnam is increasing at the rate 7-8% a year. In some cities/provinces around 10%-20% a year. This substantially increase in household income will result in a high demand of goat meat in the near future in Vietnam and in Laos. Currently, approximately 35% of Lao consumers and 28% of Vietnamese consumers are willing to pay premiums for mountain goat, and those price premiums could fluctuate between 13% in Vietnam to 46% in Laos. However, two thirds of Vietnamese goat consumers are uncertain if they have consumed mountain goat due to the lack of certification and traceability.

The supply for goat meat in Vietnam is covered by domestic production and imports from Thailand and Laos that have increased dramatically since 2017, the year we completed

our SRA project. During 2017, on average 600 goats went across the Lao Bao border weekly, a substantially smaller amount in comparison to 8,000 goats crossing the Lao Bao border weekly in 2022, with 80% of them coming originally from Thailand via Laos.

Moreover, goat trading exhibits a seasonality in Laos, with stakeholders selling most of the goats and goat meat during winter, in the dry season between December and February. In contrast, goats and goat meat are sold the year-round in Vietnam, with a peak during spring, between February and April. Figure 7.28 contrasts the seasonality reported by stakeholders in Laos and Vietnam.

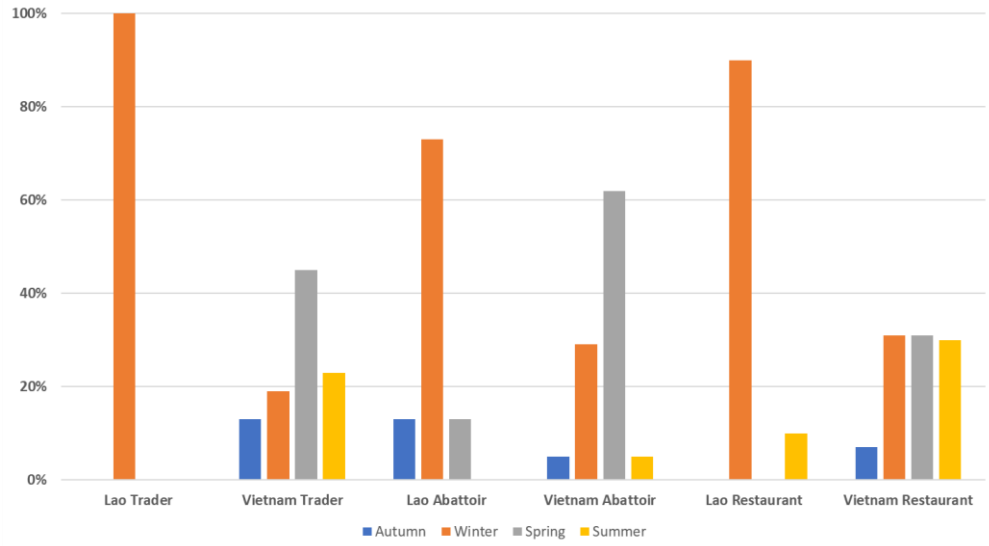

Figure 7.28: Goat trading seasonality: when most of goats/goat meat are sold.

This difference in the seasonality represents an advantage for mountain goat production in Laos, as smallholders can offer goats during a period with lower local trading in Vietnam. This could aid Lao farmers in receiving better goat prices and maintain the supply of goat meat for Vietnamese consumers.

Finally, prices paid increase dramatically as we move downstream in the value chain. In addition, this increase and price differentials are bigger in Vietnam than in Laos, as shown in Figure 7.29. These price differentials between countries at different levels of the value chain represent an opportunity for smallholder farmers in Laos to export their goats to Vietnam.

Considering all these factors, we expect good market opportunities for the Lao mountain goat production and exports due to the advantages of its location, a large domestic market and increasing exports to Vietnam.

7.3.4 Characterising domestic and export value chains

Goat farmers in Laos are small scale, mainly based on natural self-replacement and the biggest source of income comes from young goats. Goat farmers are most at risk of goat death, as diseases are the most frequent risk. Almost goats are originated from Lao goat breed, and they are of a small size of around 25 kg per head. In Laos goat rearing has a good chance to develop with minimal management and a slow-growing trend in the rearing scale. It creates economic, social, and environmental benefits, as it was the best income-generating species in the surveyed families, followed by cattle and pigs. The purpose of keeping goats is to sell them due to the high demand from Vietnam and their commercialization yields positive net income.

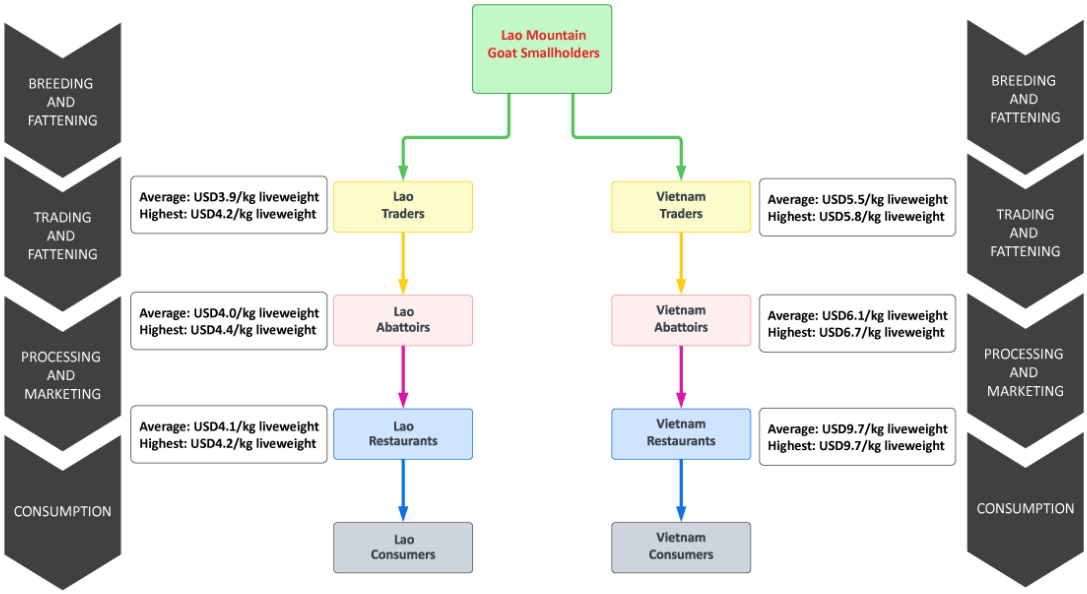

Figure 7.29: Prices paid at different levels of the mountain goat value chain in Laos and Vietnam.

This value chain is a type of export market demand-driven chain originating from Vietnamese customers. The commercialization of goats yields positive net income in Lao, and all actors get the benefits, especially traders and restaurant owners. The chain also created job opportunities and income to improve living standards, especially for disadvantaged groups in society, such as women, the middle-aged, people with low literacy and in rural areas.

Lao smallholder mountain goat farmers sell most of their goats to Lao and Vietnamese trader and Aggregators. Only a small proportion sell their goats to abattoirs and restaurants. Figure 7.30 depicts the mountain goat value chain market in Laos and Vietnam.

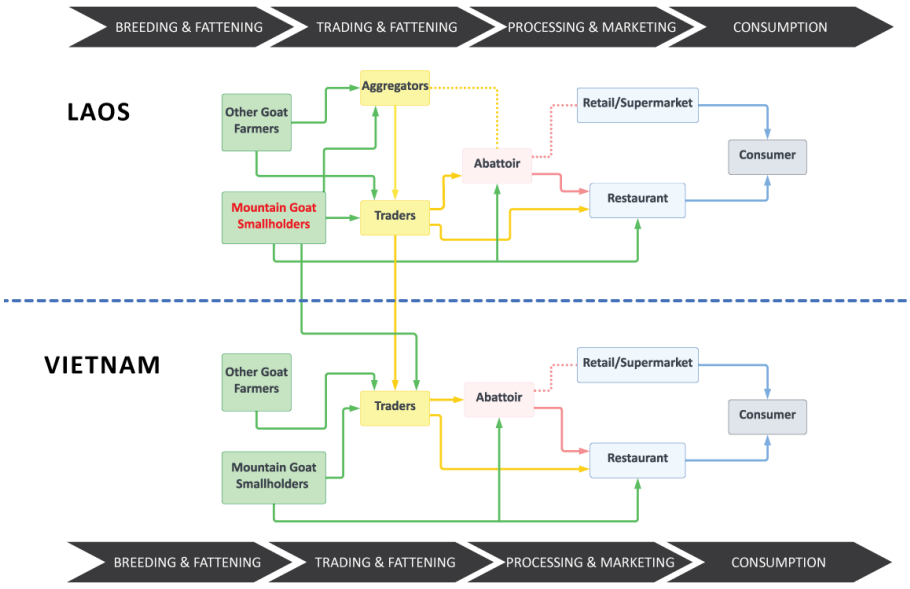

Figure 7.30: Mountain goat value chain market map in Laos and Vietnam.

Supporting stakeholders are local authorities and government; projects and NGOs; technical supporters; and license supporters. Most of the stakeholders of the value chain consider that prices are set by traders mostly, followed by the abattoirs. Lao goat market is mainly small-scale and informal with a minimum of contract farming based on oral agreements, as presented in Figure 7.31.

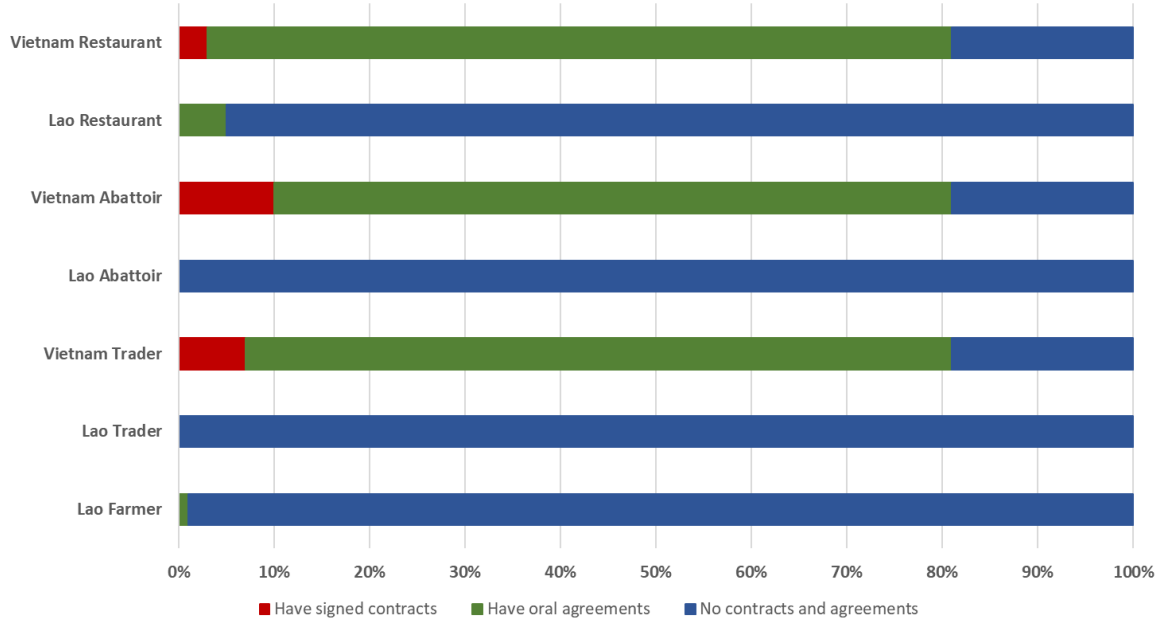

Figure 7.31: Oral agreements and signed contracts in the mountain goat value chain in Laos and Vietnam.

There is no evidence of the goat processing industry and there is no declaration of linkages among chain actors and a leader in creating cohesion and leading the actors along the chain. In addition, there is no evidence of the development of a traceability system. This informality in goat selling may negatively affect the income of smallholder farmers by decreasing the goat price received and increasing its variability; hence, reducing the incentives to produce better quality goats given the low rewards for quality. Goat prices paid to smallholders in Laos vary between approximately 400,000 kip to 2,000,000 Kip. Differences are due to characteristics of the animal, location and education of the farmer, that can be related to their capacity to negotiate (negotiation power). Profits per goat are close to the prices received, given the low amount spent on costs, mainly on veterinary products and services.

In the case of Vietnamese restaurants, they purchased live goats (47.7%) and carcasses (39.5%) with the frequency of buying goats daily (63.3%) and once every few days (31.3%). The primary supply source of goats for restaurants was local goat traders (76.2%). The goats consumed by goat meat restaurants originate from Vietnam (78.5%), Laos (20.7%), and other countries (0.8%). Most Vietnamese goat meat restaurant owners preferred Vietnam local goat breeds and Laos goats with a live weight of 20-35 kg/head. According to goat meat restaurant owners, the demand for goat meat is highly affected by season, goat raising method, income of the customers, and restaurant's business location. In addition, the price of goat meat is highly influenced by goat breed, age, live weight, sex, raising method, body condition of goat, and customer demand. The quality of goat meat is highly affected by goat breed, age, live weight, and raising method. The results recommended that further extension programs focus on improving breed's quality and raising methods for Vietnam and Laos goats to meet the quality of goat meat demanded by restaurants. The values added to goat meat was created by the meals prepared and cooked using goat meat; hence, the selection of properly targeted goats, such as type of goat, goat weight and gender, are important for restaurant owners to prepare good meals that meet the preferences of consumers in different areas.

During the COVID-19 period, there was a decline in revenue for goat meat businesses due to business interruptions of goat meat and goat meat supply disruptions. The COVID-19 pandemic negatively affected the majority of goat farmers in Laos due to rising input costs, while decreasing supply, goat production and goat sales. In addition, the price of live-weight goats declined during the COVID-19 pandemic due to unstable demand and supply. This is explained by the disruptions experienced downstream in the chain. In the case of the restaurants, the majority of them had to reduce goat consumption by more than 30% and 10-30% during the pandemic, respectively. Meanwhile, 76.5% of local goat traders had to reduce the number of purchased goats by more than 30%, and most had to stop doing business during social distancing. are noted indicators of the impacts on the goat meat consumption market.

7.4 Objective 4

7.4.1 Activity 4.1 Develop and implement Learning Alliance

The Learning Alliance resulted in 12 staff from 8 NGOs and 476 farmers from 71 villages learning about goat nutrition, housing, disease prevention/treatment and kid management. NGO staff ran farmer and veterinary village worker training courses, village meetings, monthly monitoring and created a medical fund with a committee. Women were encouraged to lead goat raising groups. One NGO (SAFE) set up a model goat farm as a learning tool.

NGO farmer uptake of practices is shown in Table 7.21, demonstrating significant scaling out of project recommendations from having a Learning Alliance.

Table 7.21: Farmer uptake of goat management practices as a result of Learning Alliance activities.

Name of NGO	Forage planting	Animal management and health	Goat pens
CBID Xaiphouthong	60	131	
CBID Kaisone		41	
WWF (Xaiphouthong, Xaibouly)		80	17
WWF (Thapangthong, Phin)		24	4
CAVA-FAO (Champhone, Xonbouly, Songlkhone and Phin)	16	80	
SAFE	10	40	
LRF (Xepon, Nong, Phin, Atsphanthong and Thapangthong)		80	20
Total	**86**	**476**	**41**

Members included The Poverty Reduction Fund, International Labour Organisation, World Vision, IFAD, SAFE (Stability of Altered Forest Ecosystems), CAVA-FAO (Climate Change Adaptation in Wetland areas in Lao PDR), and CBID (Community Based Inclusive Development USAid) and EWAII (The East-West Corridor Agriculture Infrastructure Improvement).

7.4.2 Activity 4.2 Tactical capacity training

Evaluation of the gender dimensions training showed that most were satisfied or very satisfied with training content and approaches. Trainees proposed some future training topics such as;

- Animal health package, including how to use vaccines, goat raising site selection, feeding, and breeds selection.
- Goat feeding and supplements

- ICT knowledges and skill to communicate with stakeholders
- How to diversify goat breeds
- Gender awareness raising training for farmers

District staff training in developing case studies resulted in 4 case studies which were presented at the 2022 annual meeting (see Appendix 38 & 39). This was the first time that district staff had presented at an international project meeting and they demonstrated sound understanding of farmer practice change and benefits. The district cross visits could have had stronger facilitation and indicated further training and practice is needed for staff.

Farmer training resulted in all 70 project households adopting at least one recommended practice change. An additional 60 non-project households also adopted at least one practice change. In total, 63 households planted forages, 25 improved goat pens, 87 used mineral blocks, 22 trialled supplementary feeding and 100 treated goats. See breakdown of each village and project/non-project households in Appendix 40. Animal health treatments were the most popular practice as farmers were motivated to control diseases.

Planting forages requires land and labour so some households were unable or did not want to grow additional feed. Some farmers felt there was enough feed from free grazing. However, the provision of mineral blocks was welcome and farmers noticed an improvement in goat condition. Improving goat pens and pellet feeding requires cash and labour so were not as popular.

The final benchmarking survey preliminary results also show similar trends when households were asked what were the most useful things they learnt from the project (Table 7.22).

Table 7.22: Most useful things learnt by project farmers during the project period. Data from third benchmarking survey (Objective 1).

	Most useful things learnt													
N Rate %	How to treat animal	Improved goat housing	Growing fodder crops	Maintain animal health	Right way to raise goats	Worm control	Goat care	How to feed goats	Increased profits	Supplement feed	Vaccinated goats	Weeding	Total Responses	Total Cases
All villages	12 41.4%	8 27.6%	6 20.7%	5 17.2%	4 13.8%	3 10.3%	2 6.9%	2 6.9%	1 3.4%	1 3.4%	1 3.4%	1 3.4%	46	29

7.4.3 Activity 4.3 Strategic capacity building

Despite the projects best efforts, no postgraduate student from Laos could be recruited for postgraduate training in Australia as none of the potential candidates met the English Language requirements for such degrees. However, two students from Vietnam, one from Australia and one from Sri Lanka were successfully enrolled and have contributed greatly to the project outcomes which building their capacity considerable. The students and their project/thesis titles are listed below.

- Sang van Le (Vietnam). PhD, UNE. *"Genetic diversity, inbreeding and breeding strategies for native goats in Central Laos"*. Principal Supervisor – Professor Julius van der Werf
- Preethinie Jayasekara (Sri Lanka). PhD, UNE. *"Improved diagnosis and control of major disease syndromes constraining goat production in Lao PDR".* Principal Supervisor – Professor Steve Walkden-Brown

- Eoin Liehr (Australia). M.Rur.Sc. UNE *"Sociological aspects of goat raising in developing countries, using Laos PDR as a case study"* Principal Supervisor – Dr Luisa Olmo
- Chanh Van Nguyen (Vietnam) PhD, UNE. *"Urolithiasis as a consequence of the intensification of goat production in Laos and Vietnam"* Principal Supervisor – Associate Professor David McNeill

All students are currently enrolled, making good progress and have presented their findings in various forums (including project meetings) and conferences. All will present at the upcoming SAADC23 conference in Vientiane in November 2023.

In Laos Animal Science students at SKU carried experiments on pastures (3 students) and goat nutrition (7 students) and goat parasites (2 students) supported by the project. Students also participated in many project training events. A report on this training including all of the student names and their projects can be found at Appendix 45. At NUOL Ms. Sengdavanh Xayyalath, a student at Faculty of Agriculture completed an on-farm nutrition x genetics research project, a report of which can be found at Appendix 46.

7.4.4 Activity 4.4 Initiate scaling out

Village meetings were not evaluated. Farmer practice change was monitored via monthly household surveys and final practice change data collection as shown above (Table 7.1 and Table 7.22). Evaluation of the district cross visits showed that farmers learnt how to take care of newborn kids, supplementary feeding with pellets, good housing and crossbreeding with Boer goat bucks. The visit to Nateuy large goat farm led to 9 project farmers learning how to use feed troughs, provide good water supply, use separate pens, use complete feed with rice bran and cut forages, and crossbreeding. The NGO farmer and staff cross visit to 3 project farmers resulted in learning about forage varieties, planting cuttings, using forages as supplement during wet season, good goat house designs, separating does with new kids and checking goats for parasites. These farmer learning events and regular livestock staff visits led to an increase of 500 households adopting improved goat husbandry practices.

These farmer learning events and regular livestock staff visits led to an increase from 70 project households to an additional 60 non-project households adopting one or more goat husbandry practices (total 130 households in project villages). In 2023 there were an additional 476 NGO village households adopting one or more improved goat husbandry practices as shown in Figure 7.32, below. Scaling out resulted in a total of 606 households using at least one practice change, mainly health treatments, followed by mineral blocks, forages and pen improvement.

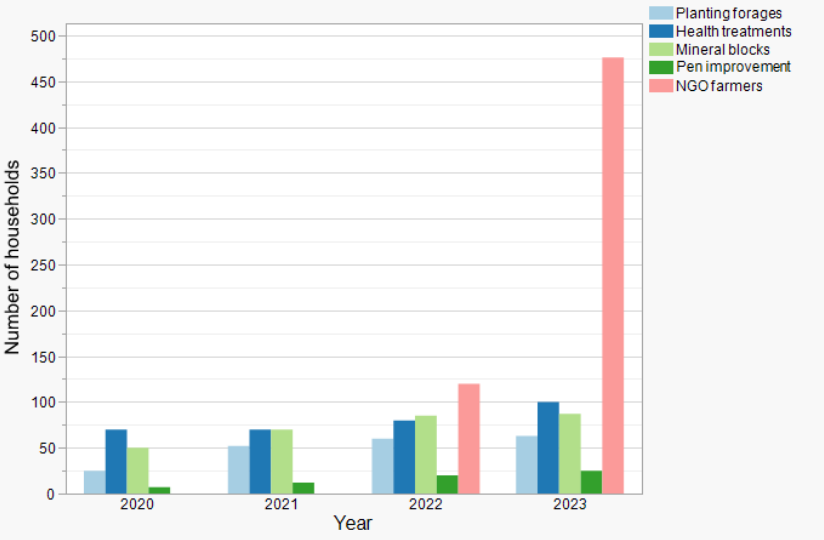

Figure 7.32: Number of households adapting improved goat management practices and number of non-government organisation (NGO) farmers using one or more improved goat management practices.

Towards the end of the project, accumulated knowledge was collated into four strategic intervention strategies which were condensed into farmer booklets which will be distributed by J Millar in November 2023 to farmers, PAFO staff, DAFO staff, Savannakhet University staff and NGO villages and NGO staff (See Appendix 41 to 44).

8 Impacts

8.1 Scientific impacts – now and in 5 years

The scientific legacy of this project will be considerable and will be accessible through the many publications that will arise from it. Twelve peer-reviewed publications are published or in submission and a minimum of a further dozen papers or more planned and likely. The main scientific impacts have been in the areas summarised below.

8.1.1 MAD technology

The use of CommCare for mobile acquired data (MAD) enabled high-quality, real-time data capture and was highly valuable for both longitudinal data collection and one-off data collection surveys. The use of MAD technology to collect data for Objective 1, 2 and 3 in Laos, and Objective 3 in Vietnam, demonstrates the feasibility of capacity building within local field-teams to streamline data collection, avoid the lengthy data entry phase, and minimise data entry errors. This may encourage other agricultural development projects to adopt similar MAD collection methods.

8.1.2 Goat genotyping using the goat 50K Illumina BeadChip

The use of the powerful 50k Illumina goat SNP (single nucleotide polymorphism) chip to examine genetic relationships between goats is completely novel for Laos and has not been done in Vietnam or Thailand either. The use of this approach to determine that inbreeding is not a major issue in Lao goats and to define genetic relationships between Lao goat populations and links to international goat populations has fundamentally altered our understanding in this area. It will inform and contribute to future research on goats in South East Asia and worldwide and may well be used in future studies in Laos to deepen understanding of the origins of Lao goats and likely pathways of introduction.

8.1.3 Use of GPS tracking in free grazing goats

While GPS tracking of domesticated and wild animals has been widely used now for many years, it is a novel approach for free ranging goats in smallholder systems. When the data are fully analysed the results will provide great insight into the distribution and movement of goats under such systems in Laos, the factors affecting movements and the consequences of the free ranging. Once the GPS devices and collars were developed and tested, their physical deployment and data recovery were all carried out by the NAFRI team in Laos indicating that it is an appropriate technology there. Any future reference to goat ranging behaviour in Laos will be informed by this detailed study, and it may well trigger similar studies in different environments.

8.1.4 Disease causation and molecular diagnostics

Similar to the use of goat DNA to answer important questions about genetic relationships between goats, the use of microbial DNA and RNA to identify the presence of pathogens is of great utility worldwide, but has had limited application in Laos, and not at all for pathogens of goats. While it is unlikely that molecular diagnostic methods such as PCR and qPCR will have practical application for routine diagnostics of goat diseases in Laos, the approach taken in this project of using them to shed light on the causative agents of some major goat disease syndromes in Laos using a case-control design was very useful and effective. The work involved the NAHL which forged links with NSW DPI's EMAI laboratory through this work. This laboratory is the central veterinary diagnostic laboratory for the state of NSW in Australia. This approach has application for other disease syndromes in goats or other species in Laos.

8.1.5 Parasitology

Previous studies have investigated worm infections in Lao goats using faecal egg counts and provisional identification of species or genus by *in vitro* egg hatching, development to the infective larval stage and examination at this point. This project introduced several additional features to investigation of gastrointestinal nematode infection in goats. These included carrying out a longitudinal study to detect changes in burdens over time, undertaking an anthelmintic efficacy study and also a slaughter study to enable definitive identification of adult parasites in various regions of the gut, coupled with quantification. This work involved serious ramping up of the parasitology laboratory at the PAFO office in Savannakhet and was enthusiastically embraced by project staff, particularly project veterinarian Thaixiong Xaikhue. Indeed, it is an aspiration of Mr Xaikhue to set up his own parasitology laboratory to deploy these skills and this is something he has commenced doing, with the purchase of his own microscope.

8.2 Capacity impacts – now and in 5 years

8.2.1 Professional and scientific capacity development

MAD technology

The successful use of MAD technology by our Australian, Lao and Vietnam teams demonstrates an improved capacity for data collection that can also be applied outside the scope of the project. The team at NAFRI built on their extensive experience in survey collection by transitioning to CommCare software to collect survey data in the field. The Lao team attended CommCare training held in Vientiane from the 21-23rd October, facilitated by Dr Dave McGill. This followed a 5-day CommCare training course held in Hanoi the week before and attended by the Vietnamese project team, Assoc. Prof. Nam Hoang from Australia and Dr Ammaly Phengvilaysouk from Laos. Dr A Colvin, the project's MAD coordinator, and other Australian project team members attended a project CommCare training course in Armidale from the19-21rd August, 2019 again run by Dr David McGill. Dr L Olmo has also developed her skills in this area under the guidance of Drs McGill and Colvin. Dr A Phengvilaysouk is now proficient in "App Building" and has translated all the surveys into Lao language in the CommCare apps and making alterations to survey forms. Dr A Colvin, built all the apps for use in Objectives 1,2 and 3 and, along with Dr L Olmo trained the Vietnam team "App builders" and enumerators in December 2020 and December 2021. The ability of the app to be accessed in multiple languages broadens its application and accessibility. Both the Lao team and the Vietnam team have successfully collected very large quantities of data using the software allowing for expedited data analysis. Members of the Objective 3 team in Vietnam have indicated the importance of learning MAD skills during the project and senior members such as Dr Cuc plan to incorporate it into future project submissions.

Gender awareness

A consistent theme within the project was gender awareness and on the Lao side a formal focus on this this was initiated by a February 2021 training program designed by Dr Phonevilay Sinavong (NAFRI) and Dr Joanne Millar (UNE) and delivered by Dr Sinavong. The training program was delivered over 3 days in Savannakhet province, with 16 participants in total, from the livestock research Centre of NAFRI, PAFO, DAFO, and Savannakhet University and a report on the training can be found at Appendix 17.

GPS tracking and data analysis

In the absence of commercially collars and GPS tracking devices suitable for deployment in goats, these were designed from scratch at UNE by Mr Glen Charlton. They represented a significant improvement on the previous sheep GPS devices and the developing and testing of these devices in Australia involved significant capacity development in this space by Glen, Derek Schneider and Luisa Olmo. Online training events were then held to introduce Lao counterparts at NAFRI, SKU and NUOL to the technology (Ammaly Phengvilaysouk, Seuth Phengsavanh, Phonetheb Porsavathdy and Daovy Kongmanila) prior to preliminary testing in Laos at these institutions. During this time PhD student Sang van Le joined the project and assumed considerable responsibility for this aspect of it. Following this was online and hands on training of the field team for deployment in the project. Goats with tracking devices were caught every month and restrained while the GPS device was removed, the battery and SDS data storage miniSD card replaced, then the device switched back on and held until a satellite signal was received. Data were then uploaded into computers and sent to the team in Australia. This process has resulted in development of high-level practical skills in this area by all the participants, and high-level skills in the data processing and interpretation by Sang van Le. It is planned that fellow PhD student Van Chanh Nguyen will become proficient at using the data coupled with GIS information to link goat movements with landscape and land use types.

Disease investigation and molecular diagnostics

This work described elsewhere in the report involved significant capacity building. PhD student Preethinie Jayasekara and her supervisors (Walkden-Brown, Gerber, Olmo and Jenkins) have developed a good understanding of goat production systems in Laos, the disease syndromes observed there, and the links between the two. Preethinie, working with Drs Gerber and Jenkins has developed good design and laboratory skills in molecular diagnostics and benefitted greatly from two extended visits to EMAI to perform her assays. In Laos, Thaixiong Xaikhue carried out the bulk of the disease sampling, diagnosis and treatment work sharpening his existing skills in this area, and benefitting from a range of project training programs in disease investigation and parasitology. He acquired important new skills in parasitology from both online and hands on training, particularly a full week long training event with Mr Jim Lea of CSIRO in Savannakhet. Through Thaixiong Xaikhue and training courses he delivered, the capacity of PAFO/DAFO extension staff and goat farmers to recognise and treat diseases was considerably enhanced.

Evaluating animal and farm performance against benchmarks

Part of the intent of Objective 1 was to develop a culture amongst farmers and MOA staff of assessing performance against targets. However, this proved to be unrealistic in the Lao goat farming context where assessment of goat enterprise performance proved difficult to assess objectively, even with project resources available. This is particularly true for reproductive performance and turnoff in a situation with uncontrolled breeding and ad hoc sales. There is better potential to monitor growth performance through the use of scales and animal weighing, and the level of mortality. However, although scales were provided to selected farmers, there was not much evidence of their use. In the end there was less capacity building in this area than anticipated.

Economics and value chain analysis

A/Prof Nam Hoang and Dr Emilio Morales from UNE worked very closely with the Vietnamese project team members in the design, implementation and analysis of the

Objective 3 surveys. This was characterised by very frequent (often weekly) Zoom meetings and also multiple visits to Vietnam by A/Prof Nam Hoang. This fostered considerable exchange of ideas and capacity development in all directions. Animal scientists such as A/Profs Nguyen Huu Van Prof. Nguyen Xuan Ba and Ngo Thi Kim Cuc were able to learn skills in marketing and value chain analysis from the likes of A/Prof Hoang, Dr Morales and Dr Bui Thi Nga, while the economists and value chain experts gained valuable information about goat production and the factors influencing it from the Animal Scientists. Improvement and expansion in writing and publication skills were fostered by involvement in cross disciplinary publications.

Less senior staff at HUAF and NIAS were able to hone basic research skills, network with senior researchers and develop specific skills in using Commcare® (MAD) the effective conduct of surveys and seminar presentation skills in English. These included Le Van Nam, Nguyen Thi Mui Nguyen Viet Don and Ngo Thi Le Quyen.

Qualitative sociological research

Most people on the project had either strong scientific or economic backgrounds and were less familiar with the methods and value of qualitative sociological research. Largely through the efforts of Dr Joanne Millar many on the project were exposed to these methods. This influence led to Mr Eoin Liehr initiating a Masters degree at UNE in the field and fellow supervisors Dr Luisa Olmo (Principal) and Steve Walkden-Brown (co) learned a great deal from this approach. Eoin's work, supported by co-supervisor Dr Malavan Chittavong in Laos also had a strong influence on our understanding of the sociological underpinnings of why people keep goats in Laos, their aspirations in this regard and methods of achieving these aspirations.

Cultural exchange and understanding

This project brought together many people from divergent backgrounds and involved considerable travel and cultural exchange between participants. This has inevitably broadened the perspectives and deepened understanding and appreciation of cultural differences of nearly every participant. This is an important aspect of capacity building on the project.

Project management

This project brought together many very experienced and senior people from divergent backgrounds. Without formal expertise or qualifications in project management, many had past experience participating in and managing other research projects, including ACIAR projects. Through a process of frequent and open communication within the project we were all able to learn from the experiences and views of others and come to a deeper understanding of what can make projects thrive or fail to thrive.

8.2.2 Farmer capacity development

As reported in Sections 7.4.2 and 7.4.4 numerous farmer training events, coupled with cross visits and village learning activities contributed to building farmer capacity in goat raising. However, it is likely that the process of interacting with project staff each month and informal discussions during these, and exchanges between farmers themselves contributed to significant capacity development during the project. The main areas of capacity development were in goat housing, disease recognition and treatment, growing of fodder crops, feed and nutrition and other basic husbandry procedures. The Benchmarking 3 survey at the end of the project (Appendix 29) revealed that 97% of respondents felt that they had learned something useful in the project and 83% had made changes to management as a result. When asked to nominate the most useful things they

had had learned 41.7% identified “How to treat animal disease”, 27.6% “Improved goat housing”, 20.7% (Growing fodder crops), 17.2% “maintain animal health”, 13.8% “right way to raise goats”, 10.3% “ worm control” and <10% for a range of other learnings.

As a consequence of scaling out activities and the Learning alliance an additional 60 non-project households and 476 households associated with NGOs in the Learning Alliance adopted improved husbandry changes mainly health treatments, followed by mineral blocks, forages and goat house improvement.

8.2.3 Learning Alliance participants

LA members rated changes in their knowledge, skills, confidence and motivation after involvement in the LA as shown in Table 8.1.

Table 8.1: Learning Alliance member ratings of knowledge, skills, confidence and motivation in goat management after training (1 = no change, 2 = low increase, 3 = moderate increase, 4 = high increase, 5 = very high increase).

Learning Alliance members	Knowledge	Skills	Confidence	Motivation
Community Based Inclusive Development (CBID)	4	4	5	5
Climate Change Adaptation in Wetland areas in Lao PDR (CAVA-FAO)	5	5	4	3
World Wide Fund for Nature (WWF)	2	3	3	3
Stability of Altered Forest Ecosystems (SAFE)	4	4	5	4

Members of the LA included The Poverty Reduction Fund, International Labour Organisation, World Vision, IFAD, SAFE (Stability of Altered Forest Ecosystems), CAVA-FAO (Climate Change Adaptation in Wetland areas in Lao PDR), and CBID (Community Based Inclusive Development USAid) and EWAII (The East-West Corridor Agriculture Infrastructure Improvement).

These results show that the LA achieved significant increase in staff capacity in goat management.

LA members rated changes in farmer knowledge, skills and confidence (Table 8.2), indicating a need to continue building farmer capacity with goat raising.

Table 8.2: Learning Alliance member ratings of changes in farmer knowledge, skills and confidence in goat management (1 = no change, 2 = low increase, 3 = moderate increase, 4 = high increase, 5 = very high increase).

Farmers	Knowledge	Skills	Confidence
Community Based Inclusive Development (CBID)	3	3	3
Climate Change Adaptation in Wetland areas in Lao PDR (CAVA-FAO)	3	3	3
World Wide Fund for Nature (WWF)	3	3	3
Stability of Altered Forest Ecosystems (SAFE)	4	4	4

NGO staff said that farmers now need improved breeding techniques and goat breeds to improve goat productivity. Most thought it important to continue promoting confinement system (goat pen), fodder crop cultivation and disease prevention and treatment.

8.2.4 Undergraduate and post graduate student capacity building

In Laos the project made significant efforts to build capacity in students at the local Savannakhet University, with the support of Mr Phonetheb Porsavathdy the Head of the Department of Animal Science at SKU. Students and staff attended 4 different training events as shown in Table 8.3 and detailed in Appendix 45.

Table 8.3: Training courses attended by students and staff of Savannakhet University.

Training event	Year	Students attending	Staff attending	Total attending
Goat feeding	2021	4	1	5
Gender awareness	2021	0	2	2
Parasitology	2022	5	2	7
Parasitology	2023	2	0	2
Total		**11**	**5**	**16**

In addition, specific student research project were supported at SKU and NUOL as summarised in Table 8.4.

Table 8.3: Student research projects at SKU and NUOL supported by the project.

Project type	Year	SKU projects	NUOL projects	Total
Pastures/Fodders	2020-21	3	1	4
GPS collars on goats	2022	1	1	2
Nutrition/feeding	2022-23	3	1	4
Parasitology	2022	2	0	2
Total		**9**	**3**	**12**

As part of the process of project support for these projects, students and staff had to prepare detailed experimental protocols (including hypotheses) and budgets and these were reviewed and iterated with relevant ACIAR project staff. This process helped in developing skills beyond narrow discipline skill, but thinking and communication skills.

The 4 postgraduate students at the University of New England have also supplemented the disciplinary technical skills they are developing listed under 8.2.1 with valuable learnings by being deeply engaged in a large, international, multidisciplinary project. The students are invited to all monthly project meetings and each provides an update at the meeting. They have participated and presented at key project meetings such as the Mid-term review, Nov 2022 project coordination meeting and the October 2023 End of Project Review. Each has had to organise and budget international travel and work with teams of others to achieve objectives. Attendance at project meetings has exposed them to project management in operation and will help prepare them for later life as independent academics themselves.

8.3 Community impacts – now and in 5 years

The main community impacts of the project have centred around the 70 farmers and 7 villages directly involved in the project. Impacts have spread from project farmers to non-project farmers in these villages, and to other locations and villages through interactions on the Learning alliance.

8.3.1 Economic impacts

Goats were a major source of income in the project farms, contributing 34-41% of farm income and 20-28% of total household income on average according to benchmarking surveys 2 and 1 respectively (Appendices 28 and 27). Masters student Eoin Liehr found that goat income was used for expenses that occurred frequently or suddenly, including utility bills, medical costs, and buying food and clothing for family members. Goats had

socio-cultural purposes. Some farmers preferred consuming goats during celebratory occasions over other livestock species. Farmers raised goats to satisfy specific financial and socio-cultural obligations that were not strictly profit maximising. Unique benefits associated with goat raising may not necessarily increase as a result of increasing the scale of the goat enterprise. Farmers may not benefit from significantly increasing the scale of their goat enterprises if it substantially increases time and labour requirements, causing unsustainable trade-offs to their other enterprises. Improved kid management, goat house-design and disease management are likely to increase goat productivity, enhance goats' subsistence and socio-cultural roles, and benefit the wider farming system. Reducing goat death and disease and improving housing is most compatible with farmers' low-risk approach to goat management. When promoting and assessing goat productivity, development interventions and outcomes should extend beyond goat performance, and target whole farming system outcomes.

The final benchmarking survey preliminary results showed most households have increased their goat income by changing management (Table 8.5). Cost of raising goats and labour requirements has not changed significantly. Disease incidence was reported by 84% of respondents to have reduced and kid mortality decreased (92% of respondents).

Table 8.5: Change in income as a result of changing goat management practices over the last 4 years (2020-2023). Data from 3rd benchmarking survey.

N Share %	Income change by changing goat management			
	Increased goat income	**No change in goat income**	**Decreased goat income**	**Total Responses**
All	16 64.0%	7 28.0%	2 8.0%	25

8.3.2 Social impacts

The main positive social impacts of this project are related to increased household confidence and competency in goat production and resultant improvement of living standards. Direct project support in the form of subsidized mineral blocks, support for fencing and forage establishment, improved goat housing and participation in training events and cross visits will also have contributed to this and increased awareness of the possibilities available. Goat raising is a gender shared activity, and as such fosters gender awareness and equality in rural communities. At a high level the project, by supporting significant income generating activity in rural villages supports economic activity and development in these areas, slowing urban drift and the problems associated with that.

When surveyed about their feelings on being involved in the project in Benchmarking survey 3 (preliminary results) 27% were "strongly positive" about their involvement and 67% "positive" while only 7% were neutral or ambivalent about it. This suggest that there were clear benefits to farmers, probably both social and economic, from being involved in it.

The Learning Alliance resulted in an additional 467 farmers improving goat husbandry practices in an additional 71 villages in Savannakhet province (CBID 34, WWF 17, CAVA 4, SAFE 8 and ILO 8). LA members were asked what was needed to support farmers to continue goat raising in the future. Responses included;

1. Access to make marketing information,
2. Access to pharmacy shops,
3. Waste management, including goat pens and manure management
4. Action plans and monthly monitoring to help farmers resolve problems.
5. Retraining VVWs and farmers

6. Organizing exchange knowledge between best farmer and poor farmer for improving skills at least once per year

7. Create a network for farmers who raise goats

8.3.3 Environmental impacts

Assessment of environmental impact was not a major activity in this project, but subjective assessment supported by photography was conducted under Objective 1. Goats have significant potential to cause overgrazing and erosion, particularly on steep slopes, and also to damage crops and vegetable plots due to the free ranging production system. As detailed in Section 7.1.4 reported livestock numbers increased overall in the villages during the environmental survey period, moderate crop damage was caused by goats in some months and considerable bare ground was visible at the end of dry periods. However, there were no observed or reported effects of goats on water quality and erosion.

8.4 Communication and dissemination activities

The project has a web site at https://lao-vietnamgoats.com/ where many of the stories, news and communication events are available, together with publicly available training materials. The site also has a login section containing presentations and material from the project Mid-term and End of Project Reviews.

The main forms of communication and dissemination of information in this project have been as follows.

1. Monthly project meetings. This facilitated communication of project findings and other developments among the institutions associated with the project.
2. Presentation of project findings within project institutions. Scientists and students on the project have made numerous presentations within their universities institutes to disseminate findings as part of the normal institutional seminar series.
3. Presentation of project findings at formal project meetings (inception meeting, mid term review, 2022 Annual Coordination Meeting and End of Project Review)
4. Involvement and communication within other like-minded groups. Luisa Olmo was an active member of RAID (Researchers in Agriculture for International Development) while Joanne Millar is also active on Lao development discussion groups such as LaoFAB.
5. The Learning Alliance in Laos was a formal mechanism for disseminating project information as described in the sections above
6. Participation in scientific and other conferences. The extent of this can be seen in Section 10.2 (Conference presentations). Project personnel have or will present at conferences in Australia, Vietnam and Laos.
7. Contributions to ACIAR newsletters
8. Generating news stories for publication within partner institution publicity systems. Some of these are captured on the project web site.
9. Publication in the formal peer reviewed literature. This has been done in English, Lao and Vietnamese publications (Section 10.2 Peer Reviewed publications).

9 Conclusions and recommendations

9.1 Conclusions

1. Early adoption and training in MAD (CommCare) was critical to achieving project outcomes particularly during the COVID-19 travel restrictions.
2. Goats fulfil an important agricultural niche in smallholder mixed farming systems in the target area, generally being a low input - moderate output component of these systems. They provide a modest sized, semi-liquid asset that is readily converted to cash with comparatively little effort. The motivations for keeping goats are not all purely economic and many farmers do not wish to expand or change their goat enterprise substantially.
3. The dominant production system relies on goats harvesting “free” food resources from private and communal lands. Attempts to improve the nutritional status of the goats require careful socio-economic analysis as they tend to require additional inputs of money and/or time. Both of these are scarce resources in these systems.
4. For the reasons above, careful targeting of extension messages and interventions is required, informed by deep socioeconomic understanding of individual farmer aspirations.
5. A detailed genomic study revealed that Lao goats are genetically close to those from China, Mongolia and Pakistan and in the target area exhibit low genetic diversity but also a low inbreeding coefficient.
6. The orf, pinkeye and pneumonia syndromes endemic in Lao goats each appears to have a dominant causative agent that the project has identified. This will assist with specific control of these syndromes. Gastrointestinal nematode infection can be serious when conditions favour it but overall is not a major health issue for Lao goats under extensive grazing conditions. Current anthelmintics available in Laos are effective. The project was unable to find sufficient cases of active diarrhoea or bloat, to enable formal investigation of these reportedly important syndromes.
7. The availability of feed is very seasonal in the target area with a long dry period between November and April. This affects goat productivity and can result in environmentally damaging overgrazing. The project explored use of fodder plots and strategic supplementation to overcome the seasonal feed shortage but insufficient definitive results were obtained to determine the socioeconomic feasibility of these approaches for most farmers. Typical grazing times for free ranging goats were also suboptimal for good productivity.
8. The goat meat supply chain is characterised by informality with an absence of regulation and organisation of goat markets, movement, slaughtering facilities and meat retail outlets. Goats are sold on an *ad hoc* basis to traders who aggregate goats for sale and slaughter at abattoirs or restaurants where most goat meat is consumed. While greater regulation and organisation could be advantageous to large commercial producers, it is not clear that it would benefit smallholder producers.
9. Goat meat is an expensive and sought after meat in Vietnam but there was no evidence that Vietnamese consumers prefer meat from Lao goats over Vietnamese goats. Ongoing growth in the sector is likely dependent on continuing economic growth and incomes in both countries and their ability to increase supply.
10. The project was successful in having farmers adopt a range of improved goat husbandry practices, but the persistence of these practices beyond the life of the project is uncertain. In the case of improved housing and fenced permanent fodder plots persistence is more likely.
11. Similarly, the project appeared to have significant positive economic and social impacts at the farmer and provincial and district advisory levels, but the persistence of these impacts beyond the life of the project is uncertain. The

scientific impacts and capacity building are likely to be more durable and captured in publications and personnel trained at various levels up to postgraduate level.

9.2 Recommendations

1. Attempting to significantly alter the smallholder production system in Laos is difficult and perhaps not warranted as the current system has evolved to meet smallholders needs. The opportunities most likely to provide durable positive effects for smallholders and national goat production include:
   a) Support for improved above ground housing. The project leaflet on this is a good starting point.
   b) Provision of improved animal health services, primarily through access to effective medications and advice from trained advisors. This could be through the PAFO/DAFO system as has been implemented in other countries such as Fiji.
   c) Support for a model for improving and managing communal lands for grazing on a village basis. As a communist country with strong communal systems, Laos has a better chance of implementing this and overcoming the “tragedy of the commons”, than many other countries
   d) Provision of a wide range of appropriate plant propagation material to farmers on an ongoing basis, possibly through the PAFO/DAFO system. Species suitable for both forage production and ability to persist in the face of heavy grazing pressure and dry periods should be available. Universities, schools and other social organisations could be encouraged to propagate and disseminate species found to be successful in particular areas.
   e) Encouraging the exchange of breeding bucks between farms and villages
   f) Formally evaluating the consequences of crossing Lao goats with improved breeds of meat goat such as the Boer and Bach Thao.
   g) Encouraging farmers to maximize the daily grazing time available for goats
2. The small size of goats and comparative ease of transport and slaughter mitigate against highly organised and regulated marketing, slaughtering and meat inspection facilities. The unregulated trade in goats poses risks of disease transmission, food safety and lack of provenance information on the final product. However, these risks are not borne by the smallholder producers who would likely share the increased costs of a more regulated trade without sharing the benefits. Based on this background the following are recommended:
   a) A complete overhaul to regulate the live goat trade within and from Laos is not warranted and is possibly beyond the current resources of the Lao Government.
   b) Rather an evolution in regulatory control based on learning from the experience with the cattle export trade and certification should be adopted.
   c) There is an opportunity for entrepreneurs in Laos to produce and market finished packed goat meat for export to Vietnam, providing certification, provenance and quality assurance. The government of Lao PDR should support such initiatives.
3. Capacity building efforts in Laos on this project were limited in some cases by the level of English language capability of Lao counterparts and in some cases insufficient technical expertise.
   a) While it is appreciated that technical expertise can be gained in many languages, English is an international lingua franca in science and technology. Supporting the development of English language skills, particularly amongst university graduates will increase the range of learning exchanges available to Lao scientists and should be encouraged.
   b) Goat production in Vietnam and Thailand is more advanced in some aspects than that in Laos, and technical cross-learning visits to these countries should be encouraged.

Disease is a major constraint on goat production in Laos, and a potential barrier to an organised trade in goats due to a lack of proper disease status certification. The

development of high-level veterinary training, in addition to animal production training at Lao universities should be encouraged. The benefits will not be restricted to the goat sector.

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10.2 List of publications produced by project

10.2.1 Peer reviewed articles – published or in submission

Bui, N, Nguyen, V, Nguyen, B, Le Van, N, Nguyen, M, Ngo, C, Hoang, N, Morales, LE, Nguyen, D, Olmo, L, Walkden-Brown, SW, Le, TTH (2023) An analysis of the goat value chain from Lao PDR to Vietnam and socio-economic sustainable development perspective. *Sustainability* **15**, 13781.

Bui, N, Hoang, N, Ngo, C, Nguyen, D (2021). Goat Value chain from Lao PDR to Vietnam. *Journal of Vietnam Socio-Economic Development*, **26(3)**, p69-80.

Bui, N, Ngo, C, Ngo, Q, Walkden-Brown, SW, Nguyen, D, Hoang, N (2023). The situation, risks and impacts of the COVID-19 pandemic on smallholder goat farmers in Laos. *Science and Technology Journal of Agriculture and Rural Development*. **8**, p221-229.

Jayasekara, PP, Theppangna, W, Olmo, L, Xaikhue, T, Jenkins, C, Gerber, PF, Walkden-Brown, SW (In submission-2023) Review of disease as a constraint on goat production in Lao PDR and trade to neighbouring countries. *Animal Production Science*

Liehr, E, Millar, J, Walkden-Brown, SW, Chittavong, M, Olmo, L (In submission - 2023) Farmer experiences with goat raising in Lao PDR: implications for improving husbandry and sustaining viable systems. *International Journal of Agricultural Sustainability*

Millar, J, Colvin, AF, Phengvilaysouk, A, Phengsavanh, P, Olmo, L, Walkden-Brown, SW (2022) Smallholder goat raising in Lao PDR: is there potential to improve management and productivity? *The Lao Journal of Agriculture and Forestry* **46**.

Millar, J, Phengsavanh, P, Phengvilaysouk, A, Xaikhue, T, Olmo, L, Colvin, AF, Walkden-Brown, SW (2023 – In submission) Facilitating farmer learning to improve goat husbandry in Lao PDR. *Journal of Animal Science and Technology Development*.

Morales, LE, Hoang, N, Olmo, L, Colvin, AF, Phengvilaysouk, A, Walkden-Brown, SW (2023 - In submission) Price discrimination, smallholders and poverty - How market orientation can affect profitability. *Journal of Development Economics*

Nguyen, B, Nguyen, V, Hoang, N, Olmo, L, Walkden-Brown, SW (2021) Goat development in Laos and Vietnam: Opportunities and Challenges. *Journal of Animal Husbandry Sciences and Technics* **269**, p2-7.

Olmo, L, Nguyen, V, Nguyen, B, Bui, N, Ngo, C, Nguyen, D, Hoang, N, Morales, LE, Walkden-Brown, SW (2023 - in submission-a) Goat meat supply chain and demand in Vietnam: global context and opportunities and risks for smallholder producers. *Animal Production Science*

Olmo, L, Nguyen, V, Nguyen, B, Bui, N, Ngo, C, Nguyen, D, Ngo, Q, Hoang, N, Morales, LE, Walkden-Brown, SW (2023 - in submission-b) Goat meat supply and demand in Vietnam: opportunities and challenges for smallholder producers in Lao PDR. *Animal Production Science*

Phengvilaysouk, A, Colvin, AF, Olmo, L, Phengsavanh, P, Millar, J, Walkden-Brown, SW (2022) Smallholder goat herd production characteristics in Lao PDR. *The Lao Journal of Agriculture and Forestry* **46**.

10.2.2 Planned Peer reviewed articles

Colvin, AF, Olmo, L, Phengvilaysouk, A, Phengsavanh, P, Millar, and Walkden-Brown, SW () Comparison of survey methods for evaluating livestock productivity in agricultural development projects: A case study of smallholder goat production in Lao PDR. *Planned journal for submission: Small Ruminant Research.*

Colvin, AF, Olmo, L, Xaikhue, T, Lea, J, Phengsavanh, P and Walkden-Brown, SW () Prevalence of internal parasites in goats in Central Lao PDR, the effect of goat management practices and the effectiveness of three anthelmintics against the major strongyle nematodes. *Planned journal for submission: Veterinary Parasitology: Regional Studies and Reports.*

Jayasekara, PP, Jenkins, C, Gerber, PF, Olmo, L, Xaikhue, T, Theppangna, W, Walkden-Brown, SW () Case control study to determine the causation of eye infection in goats in Savannakhet province of Lao PDR. *Planned journal for submission: Veterinary Microbiology.*

Le, S, de Las Heras-Saldana, S, Alexandri, P, Olmo, L, Walkden-Brown, SW, van de Werf, JHJ () Genetic diversity and population structure of Lao native goats in Central Laos and insight into origins. *Planned journal for submission: Animal, Frontier – Genetic or Plos one.*

Le, S, de Las Heras-Saldana, S, Alexandri, P, Olmo, L, Walkden-Brown, SW, van de Werf, JHJ () Signature of selection of Lao native goats. *Planned journal for submission: Animal, Frontier – Genetic or Plos one.*

Le, S, de Las Heras-Saldana, S, Alexandri, P, Olmo, L, Walkden-Brown, SW, van de Werf, JHJ () Home range use and overlap between Lao native goat herds. *Planned journal for submission: Animal, Frontier – Genetic or Plos one.*

Nguyen, VC, Nguyen, NB, Colvin, AF, Phengvilaysouk, A, Phengsavanh, P, Olmo, L, Cowley, FC, Walkden-Brown, SW and McNeill, DM () Household and management characteristics of free-range goat production system in Laos associated with live weight response. *Planned journal for submission: Small Ruminant Research.*

Nguyen, VC, Le, S, Cooper, T, Phengvilaysouk, A, Phengsavanh, P, Olmo, L, Cowley, FC, Walkden-Brown, SW and McNeill, DM () Assessing Lao local goat grazing patterns using GPS in relation to productivity in the free-range production system. *Planned journal for submission: Small Ruminant Research.*

Nguyen, VC, Do, V, Cowley, FC, Walkden-Brown, SW, McNeill, DM () Metabolic response to calcium supplementation in fattening goats fed a high phosphorus diet in Vietnam. *Planned journal for submission: Small Ruminant Research.*

Olmo, L, Phengvilaysouk, A, Colvin, AF, Phengsavanh, P, Millar, J, Walkden-Brown, SW () Factors associated with goat productivity on smallholder farms: a case study from Lao PDR. *Planned journal for submission: Small Ruminant Research.*

10.2.3 Conference papers

Bui, N, Ngo, C, Ngo, Q, Nguyen, V, Nguyen, B, Le, N, Nguyen, M, Hoang, N, Morales, LE, Nguyen, D, Olmo, L, Walkden-Brown, SW (2023a) 'Can goat rearing create sustainable benefits for smallholder producers in developing countries? An exploratory story of Laos., International Conference on Sustainable Animal Agriculture in Developing Countries.' Vientiane, Lao PDR, November 2023.

Bui, N, Nguyen, V, Nguyen, B, Le Van, N, Ngo, C, Ngo, Q, Hoang, N, Morales, LE, Colvin, AF, Nguyen, D, Walkden-Brown, SW (2023b) 'Goat production systems and marketing in Lao PDR and Vietnam -Poster, The 5th Annual Conference on Animal and Veterinary Sciences.' Ha Noi, Vietnam, 5-7th October 2023. (The Journal of Agriculture and Development:

Colvin, AF, Olmo, L, Phengvilaysouk, A, Gray, GD, Phensavanh, P, Walkden-Brown, SW RB E. Charmley, S.S. Chauhan, D. Innes, S. Muir, L. Watt and C. Wilson (Ed.) (2022) 'Smallholder goat production systems in Lao PDR: assessing production efficiency, Australian Association for the Advancement of Animal Science.' Cairns, Queensland. (Animal Production Science. Available at https://www.publish.csiro.au/AN/pdf/ANv62n11abs

Hoang, N (2023) 'Goat's value chain from Lao PDR to Vietnam: Current situation, issues and policy implications., International Conference on Sustainable Animal Agriculture in Developing Countries.' Vientiane, Lao PDR, November 2023.

Jayasekara, PP, Jenkins, C, Gerber, PF, Olmo, L, Xaikhue, T, Theppangna, W, Walkden-Brown, SW (2023) 'Causation of pinkeye in goats in Savannakhet province, Lao PDR, International Conference on Sustainable Animal Agriculture in Developing Countries.' Vientiane, Lao PDR, November 2023.

Le, N, Nguyen, V, Nguyen, B, Nguyen, M, Pham, H, Van, P, Bui, N, Ngo, C, Nguyen, D, Hoang, N (2023a) 'Vietnamese Goat Market: Insight from goat meat restaurant owners' survey., International Conference on Sustainable Animal Agriculture in Developing Countries.' Vientiane, Lao PDR, November 2023.

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11 Appendices

Appendix 1: Full list of participants in the project

Appendix 2: Benchmarking-1 Questionnaire

Appendix 3: Benchmarking -2 Questionnaire

Appendix 4: Benchmarking -3 Questionnaire

Appendix 5: Monthly household survey Questionnaire

Appendix 6: Doe Monthly survey Questionnaire

Appendix 7: Kid Monthly survey Questionnaire

Appendix 8: Quarterly Environment Survey Questionnaire

Appendix 9: Village registration data

Appendix 10: Household monthly survey data summary - Smallholders

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Appendix 17: Gender training report

Appendix 18: Farmer training Forages 2020

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Appendix 24: Household monthly survey Data summary - Large farms

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Appendix 26: Benchmarking-1 Data summary - Smallholders

Appendix 27: Benchmarking-1 Data summary – Large farms

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Appendix 29: Benchmarking-3 Project Impacts – 30 farmers

Appendix 30: Quarterly environment survey data summary

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Appendix 32: Parasitology explanatory variables

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