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1 Acknowledgments

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Vinaka vakalevu & Fa'afetai tele lava

2 Executive summary

The Pasifika Sheep and Goat Improvement Project (PSGIP) was launched in October 2019 and shortly after that affected by COVID-19 restrictions on travel and activities between and within the project countries. A 15-month extension was then granted in order to finish the project by June 2024. This project was designed and planned to be delivered over a 4-year period, but vast majority of activities were conducted between January 2022 and June 2024 (~2.5 years). Nevertheless, the project team and partners committed to the task of achieving the proposed milestones and were able to complete the majority of the project objectives. Apart from several on-farm and on-station biophysical research trials, and several social and economics research activities, the project also successfully implemented a production monitoring program with a total of 39 farms in Fiji (n = 19) and Samoa (n = 20) for a period of approximately 2.5 years. During this program the farmers working together with the project team and individually monitored a total of 3,809 animals, recording the information of 1,591 births, 709 sales/home consumption/gift and 764 farm expenses in farms that had no culture of farm-record keeping previously. This dataset provided an opportunity for a much deeper understanding of the productivity levels and challenges faced by Fijian and Samoan farmers.

The project activities initiated with a large baseline survey which reached 184 households across Fiji (Wester and Northern Division) and Samoa (Upolu and Savai'i). The results showed significant differences between countries and to a lesser extent some differences between locations within countries. Fijian small-ruminant farmers seem to be of a lower socio-economic class when compared to Samoan farmers, where a larger proportion if respondents were distributed among higher income brackets and attained higher education levels. In addition, Fijian farmers were less likely than Samoan farmers to hire a full-time employee but would commonly hire casual labour to help with specific tasks (e.g. fencing or drenching). A low proportion of Fijian farmers and their family members reported to have an off-farm income, while in Samoa this was the norm for most of the families. The overall size (land area and flock/herd size) of the small ruminant business was larger in Fiji than in Samoa while farms in Samoa seemed to have a higher diversity of crops among their enterprises. In relation to management practices, overall, there is small adoption of feed supplementation (e.g. mineral, fodder or concentrate) and these practices were more common observed in the most populated areas of both countries, compared to the outer islands. In Samoa, farmers have little knowledge in regard to the type anthelmintics utilised in their properties while in Fiji farmers are aware since most of them are responsible for administrating the drugs. Most farmers in both locations of Fiji identified dog predation as the worst problem in their enterprises. Meanwhile, in Samoa, dog predation was more commonly mentioned in Upolu and a lack of information was the biggest constraint identified by farmers on Savai'i. Faecal samples collected during the baseline survey demonstrated extremely high infection levels during the Wet season (mean 1,203 epg), and lower, but still high worm infection levels in the Dry season (mean 411 epg). There was a significantly higher level of worm infection in young stock (934 epg) and lactating females (701 epg) when compared to dry adults (453 epg). Surprisingly, gastrointestinal nematode burden was very low in Samoan sheep farms (< 150 epg).

Two large on-farm trials were conducted to understand: (1) the level of anthelmintic resistance on Fijian small ruminant farms (n = 12 farms) and (2) the production impact of ineffective gastrointestinal nematode control (n = 19 farms). Both trials were conducted on private farms which were representative of the country's production systems. We initially hypothesised that a significant anthelmintic resistance problem would exist in Fijian small ruminant farms. Our findings confirmed that a significant level of resistance exists for albendazole at the registered dose (65.2% FECR), however levamisole (current commercialised drug by MoA) still has a reasonably high level of efficacy (91.6% FECR), despite it being lower than the commonly adopted research threshold of 95% FECR. A combination of levamisole and albendazole provided an average of 94.3% FECR while ivermectin and moxidectin were highly effective (97.4 and 98.8%, respectively). The results obtained through the production impact trial also demonstrated that animals “free of worms” were no more productive than animals receiving the “usual” worm control protocol of each farm. Taken together these results indicate that despite being a potential problem at times (e.g. wet season) and for specific animal classes (e.g. young animals/lactating females) the overall level of efficacy of the current commercialised drench (i.e. levamisole) is still satisfactory and does not explain the low levels of productivity observed. However, considerations in relation to adoption of combination drugs in order to extend the efficacy of levamisole are provided in our reports.

Several research trials were also conducted at research stations to evaluate different possible technological interventions such as: post-weaning supplementation, creep-feeding, fodder production, long-acting drenches and quality of silage using local available resources. The trials suggests that creep-feeding technologies have a good potential to provide an improvement in animal performance and still be economically viable. The post-weaning supplementation strategy provided a significant benefit in performance (86 vs 62 g/head.day), but it did not translate into a better economic performance. Juncao grass (green and purple varieties) have been introduced to Fiji as part of the Chinese aid program and promoted as highly productive and nutritious fodder. However, there was no previous published research providing recommendations for management of these varieties or comparisons with other common folders already present in Fiji such as Guatemala or Elephant grass. A two and a half year research trial was conducted at Sigatoka Research Station and provided management recommendations as well as nutritional value benchmarks for these fodder species that should be considered when recommending the utilisation of these fodders.

The gender equality and social inclusion component of this project conducted a deep investigation on the family structure, behaviour, preferences of small ruminant farmers in Fiji and Samoa. It was detected that in Samoa, given the more recent introduction of sheep, the gender roles are not as well defined as in Fiji, where sheep and goat have been a tradition of some families over multiple generations. In addition, it highlighted areas in which women farmers had interest in increasing their knowledge (e.g. business management, animal care and health) which was later provided as a group training through the project. In addition, this component developed GESI Research and Extension Guidelines which specified a series of considerations that should be taken during planning of research and extension activities in Fiji and Samoa. We have noticed that women in general took an important leadership role in farm record keeping (e.g. deaths, births, sales etc..) during the on-farm monitoring program, and they became significantly more involved and interested in the enterprises when that happened. We could also note that women would have a more detailed accountability and accuracy of recordings.

The on-farm monitoring program revealed that the most significant losses in small ruminant production systems in Fiji and Samoa is caused by “missing animals” which account for 9 to 28% of reproductive females within a year. In addition, analysis of reproductive performance demonstrates that on average 17.2 to 40.7% of dams would not give birth within a year. Despite these extreme high levels of inefficiencies, Fijian small ruminant farmers still make an average net monthly income of FJ$500/month from their small ruminant production, which represents at least 50% of the average reported household income of most Fijian farmers. The prices received by farmers, in Fiji and Samoa, at gate sales are impressively high (approximately double) when compared to current prices paid to farmers in Australia or New Zealand, and quite often similar on a liveweight basis to prices of meat retailed at local supermarkets or butchers. The on-farm monitoring also demonstrates that 80 to 90% of all turned-off animals go to farm-gate sales and only a small proportion is utilised for home consumption or gifts, which contradicts recent official estimates from the Fijian Agricultural Census (2019). There is a large potential for high profitability in sheep and goat farming which is currently corroded by structural problems that not often can be resolved inside the gate (e.g. missing animals from dog predation and thefts) and require a combined effort by other sectors of the government and society.

The project has made efforts so that the knowledge generated through the many research activities is disseminated and that personnel trained are absorbed by the Ministries. In a partnership with Fijian Ministry of Agriculture and Waterways and Fijian High Education Commission, the project has funded and supported the development of a National Certificate Level 2 course in Small Ruminant Production, building on the knowledge gained in the project, and institutionalising it in Fiji. This course will be offered to local producers and will ensure that the knowledge developed through this project will continue contributing to improve production of sheep and goats on the following years. In addition, out of the 6 project officers hired in Fiji and Samoa, 5 of them have already been hired either through the Ministries or other research projects.

Overall, the project was able to provide a much deeper understanding of small ruminant production systems in Fiji and Samoa. However, given the time limitation we were not able to extend out as much of the technological on-farm interventions as originally planned. However, the project has developed a list of recommendations and suggestions for Fijian and Samoan Ministries of Agriculture as well as farmers that have the potential to support the expected growth of this industry on the years to come. It's clear that demand and production of sheep and goats in Fiji and Samoa will continue to expand over the next years but it will depend on the Government bodies to provide the resources, information and capacitation necessary for this growth to be achieved in a sustainable way.

PASIFIKA
SHEEP AND GOAT IMPROVEMENT PROJECT

3 Background

The genesis for this project was identification of a need an opportunity to improve the small ruminant sector in Fiji and Samoa by several key local stakeholders. This grass-roots proposition ultimately led to the Pasifika Sheep and Goat Improvement Project (PSGIP – LS/2017/033). However, the project was preceded by an ACIAR-funded Small Research Activity (SRA - LPS/2016/021) which together with the available literature provided the initial background information that allowed the development of the research questions and objectives for the PSGIP. Fiji and Samoa were selected not only for the current economic, social and cultural importance of small ruminants for its communities but also for the potential for expansion of the domestic production in order to supply local and international markets. In addition, the PSGIP was developed in partnership with the "Sectoral analysis and investment requirements for improving the small ruminant sector in Fiji and Samoa" (LS/2018/183) project which provides a more in-depth analysis of the small ruminant meat value chain and market while we have focused in constrains inside the gate.

Fiji has a diverse population that in 2007 was composed of approximately 884,887 people where 57% were iTaukei Fijians, 37% Indo-Fijians and 6% of other ethnicities (e.g. European, Chinese and all others) (Fiji Bureau of Statistics 2008). Approximately 24% of the population are Hindus and don't consume pork or beef and 6% are Muslims and don't eat pork (Fiji Bureau of Statistics 2008). These characteristics help to explain the social importance of small ruminants in these communities. In 2022, Fiji spent a total of US$28.6 millions importing sheep meat (5.6 kt) and US$459 thousands in goat meat (79 t) which represented 55% of the total meat imports in value for that year (Chatham House 2024). The small ruminant population in Fiji is heavily concentrated in the Western and Northen Division of the country, with these two locations accounting for approximately 95% of all sheep and goats (Ministry of Agriculture 2020). The Samoan population is smaller and much more homogeneous in terms of ethnicity and religious cultures compared to Fiji. The last census in 2021 recorded 205,557 habitants where 93 % are Samoans, 6.5 % Euronesians, 0.3% Europeans and 0.1% others. The great majority of the population (98%) are Christians (Samoa Bureau of Statistics 2022). In 2022, the country imported US$4.5 million dollars of sheep meat (2^{nd} largest commodity import in value – 1.4 kt) (Chatham House 2024). The consumption of sheep and goat meat in 2021 varied from approximately 5.4 to 2.5 kg/capita for Fiji and Samoa respectively, and in both countries, poultry is the main type of meat consumed (FAO 2023). Despite having a relatively low consumption per capita, sheep and goat meat represent a significant expenditure for both countries and one that could be substituted for by local production. Estimates showed that approximately 88% of the sheep and goat meat consumed in Fiji was imported and an even greater disparity would exist in Samoa (MOA 2016; Cowley *et al.* 2019).

Before this series of recent projects (i.e. LS/2017/033, LPS/2016/021 and LS/2018/183) the last ACIAR group of small ruminant funded research in Fiji was conducted in the late 1980's. These previous projects focused on internal parasite control and achieved significant improvements in terms of knowledge and capacity building which was lost throughout the years by a hiatus of investments in the sector and political issues (e.g. military coups). The sheep sector in Samoa is very young, with the first governmental efforts to introduce it in Samoa happening in 2004. Despite its recent start, the industry has been growing at a fast pace jumping from 249 to 1,654 animals in the decade 2009 to 2019 (Samoa Bureau of Statistics 2021). A similar trend can also be observed in Fiji where the number of sheep more than doubled in the last ten years (14,068 to 37,435 from 2009 to 2019) and goats increased by almost 50% (101,196 to 143,853) over the same period (Ministry of Agriculture 2020). The pace of industry growth allied with the information on the level of imports of these commodities provide some hints that there is a substantial demand for these products despite its relatively higher price when compared to other protein sources (e.g. poultry or pork).

During SRA - LPS/2016/021, it became clear that Fiji and Samoa had a significant demand for sheep and goat meat and that the growing population and industry were part of a promising scenario that was favourable for technological improvements. More importantly, both government departments requested support to implement a research strategy in order to support the advancements in the sector. The Livestock Sector Strategy plan for Fiji released in 2016, highlighted the growth potential of these commodities setting up a 10-year goal of doubling production aiming to reduce poverty and reduce the dependency on imports (MOA 2016).

This project was then designed to address the constraints of low productivity observed in previous projects and research. However, despite some previous research conducted on the past, there was a lack of information in relation to the characteristics and productivity levels of these systems. However, the findings obtained during SRA as well as discussions with local experts (MOA, MAF, USP and FNU) were utilised to elaborate the objectives and research questions of this project which are described in detail over the following sections.

4 Objectives

The PSGIP aimed to improve the livelihood of smallholder and semi-commercial sheep and goat producers in Fiji and Samoa by providing information and support for farmers to deal with their on-farm productivity constraints.

The project had three main objectives which were directly related to the research questions developed:

1. Assess the productivity of current production systems in Fiji and Samoa, and understand the costs, benefits and motivations for men and women farmers to make improvements (Research Questions 1, 2, 8 and 9; 35% of project effort);
2. Test innovations to improve husbandry and feeding systems so as to better manage feed gaps, reduce mortality and improve small ruminant turn-off rates in Fiji and Samoa (Research Questions 3, 4 and 9; 35% of project effort);
3. Evaluate the effectiveness of current worm control strategies in Fiji and Samoa, and develop options for improving worm control and use of anthelminthics (Research Questions 5, 6, 7 and 9; 30% of project effort).

The objectives and research questions developed for PSGIP were the result of several activities (e.g. key informant interviews, farm surveys, group discussions and on-farm surveys) and knowledge developed during the SRA LPS/206/021 and refined during the workshop conducted with representatives of MoA Fiji, MAF Samoa, USP and SPC held in Suva. Based on these discussions the following research questions were defined:

1. What is the current variation in production systems, feed resources and young animal losses in Fijian and Samoan SR farms?
2. What is the scale, causes, and solutions to young animal losses in sheep and goat flocks?
3. How can better flock husbandry and management improve the turn-off of weaners per breeding female?
4. How can home-grown and locally-sourced feed resources be integrated into Fijian and Samoa production systems and livelihood strategies to reduce feed gaps and increase breeding efficiency and weaner turn-off?
5. To what extent is SR production in Fiji and Samoa constrained by gastro-intestinal parasitism?
6. What is the scale and severity of anthelmintic resistance in semi-commercial and smallholder herds, and which practices are promoting anthelminthic resistance?
7. How can parasite management be improved so as to control the impact of worms, and reduce the cost of production without promoting drench resistance?
8. What are the impacts of different SR production systems and market destinations on rural livelihoods and the environment?
9. What are the decision-making considerations by men and women farmers (eg. production system, social and whole-farm activities and income sources) which affect the adoption of on-farm technologies?

Based on the objectives and research questions a series of research activities and a capacity-building program was developed. We will provide a description of the methodology utilised and results of these activities in section 5, 6 and 7. We will then attempt to answer each research question in section 9.1 based on the results obtained through the project.

5 Methodology

In order to improve the comprehension of this report we will subdivide section 5 and 7 into subheadings based on the research activities conducted. The outcomes of all these activities will then be merged and discussed together in sections 8 and 9. In Fiji, we have focused our research efforts in the Western and Northern Division of the country given that is where more than 95% of the small ruminant population is located.

Animal and human ethics approvals were obtained before conducting the research described in this document. The procedures adopted in this study were in accordance with Australian Code of Practice for the Care and Use of Animals for Scientific Purposes, Australian Code for the Responsible Conduct of Research and approved by the University of New England animal (AEC20-113; AEC20-021; ARA21-110; ARA22-039; ARA23-016) and human ethics (HE22-094; HE21-219; HE24-077) committee.

5.1 Review of small ruminant research in Fiji and Samoa

This review builds on information provided by previous reviews of small ruminant research in Fiji (Turbet 1929; Walkden-Brown 1984; Walkden-Brown 1985, 1986; Walkden-Brown and Singh 1986; Manueli 1991; Manueli 1995; Manueli 1997) as well as database research on more recent research activities focused on small ruminant production in Fiji and neighbouring Pacific Island countries. To provide a more complete picture about technologies currently being used in small ruminant production in Fiji a few key informant interviews were also conducted.

A search for peer reviewed studies was conducted using a systematic search of multiple databases. Additional resources were also included in the reviewed literature. The following databases were included: Scopus, Web of Science, Pacific Community online library, Pacific Agricultural Information System Document Search, ARIS database.

Four interviews with current extension experts from the MoA and one member of the MoA research division focusing in their work on small ruminants were interviewed in July 2024. The interviews were conducted one-on-one via Zoom using an interview guide. The automated Zoom transcript was checked and completed using Nvivo12 which was also used to conduct a content analysis of the interviews following (Hay 2016). Prior to the interview an information and consent form was discussed by the interviewer and left with the interviewees. A summary of the interview was shared with the interviewees for their feedback and the interviewees then returned the signed information and consent form to the interviewer. Information from the interviews is presented in an anonymous form in accordance with the agreement signed by the interviewees.

5.2 Gender equality and social inclusion

In this project, the Gender and Social Inclusion (GESI) component was delivered as a mainstreamed approach, rather than a stand-alone activity. The GESI strategy was delivered through three interlinked components: (1) Technical Advice, (2) Research, and (3) Training and Capacity Building, implemented in conjunction to amplify the impact.

While equipping the project with relevant expertise by recruiting gender specialists, the GESI strategy implemented capacity building activities aimed at enhancing awareness and knowledge among project staff and the broader Ministry of Agriculture team. This was achieved through ongoing technical assistance, capacity building training, discussions and *learning by doing* sessions. The research components and the related tools were designed to capture women's experiences, perceptions, and aspirations within the SR sector, addressing gaps identified during the 2016 SRA. The research methodology implied consequential steps to gather comprehensive insights into gender and social inclusion within the SR sector, including key informant interviews, focus group discussions (FGDs), and a follow-up validation process to authenticate the data.

The FGDs were chosen as preferred research tool to capture the collective experiences of women farmers and to gain an in-depth understanding of gender and social issues. To create a safe space and facilitate participation, FGDs were conducted with separate groups for women and men. The project conducted a total of 13 FGDs in Fiji and Samoa reaching out to 169 sheep and goat farmers of which 96 were women participants. Specifically, 9 FGDs were conducted in Fiji in both Western Division and Northern Division over March and April 2022 with a total of 93 sheep and goat farmers (61 women); 4 FGDs were organized in Samoa in both Upolu and Savaii Islands in October 2023 involving 75 sheep farmers (35 were women) on both islands. The findings obtained during the FGD's were processed, summarized and validated through another series of community based focus groups discussions. The validation reached out to a total of 117 farmers (73 woman) being 71 from Fiji and 46 from Samoa. Following data validation, an in-depth analysis was conducted and summarized in a report, which outlines findings, lessons learned, and key recommendations for gender-responsive interventions.

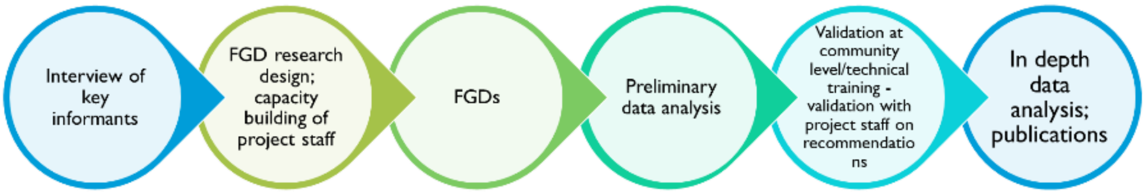

Figure 1: Summary of the methodology applied during the elaboration of the GESI component.

5.3 Baseline survey of small ruminant systems in Fiji and Samoa.

This study was conducted in Fiji and Samoa from January 2022 to July 2024. In total 184 farmers were interviewed across four different locations – Western Fiji n= 60, Northern Fiji n= 71, Upolu n=27 and Savai'i n=26 (Figure 2). In each location, the survey was conducted by trained project officers, who conducted the interviews in the preferred language of the farmer (e.g. i-Taukei, Hindi, Samoan or English). The farms were selected based on a list of registered farmers provided by the Fijian and Samoan Ministry of Agriculture. In Samoa, the target number of farms to be interviewed was 25 for each island and in Fiji the sample size was 20 for each location (i.e. North and West) and farm type (i.e. sheep only, goats only and sheep and goats). The interviews took approximately 40-60 min and consisted of questions which aimed to provide a general description of the farmer household characteristics as well as the production system and management activities. In addition, faecal samples were collected from individual animals in order to perform faecal egg count analysis (FEC) as well as identification of gastrointestinal genera by coproculture. In Fiji these samples were analysed separately (one per animal) while in Samoa the samples were bulked per farm and broad animal class. In Fiji, we aimed to collect 10 samples from each of the following broad animal classes: 1) lactating females, dry females and adult males (i.e. rams and bucks) and 2) growing males and females. In farms where both species were raised (i.e. sheep and goats), the sampling class was also divided by species. In Samoa, the samples were bulked based on two broad animal classes: adult and young animals. It was classified as "dry season" when samples were collected between May and October, and "wet season" when collected during the other months of the year. The results were analysed using the software R (R Core Team 2019) in order to identify differences and trends between the four different locations. Numeric variables were analysed using a linear model with one-way ANOVA and categorical variables were analysed using a Chi-Square test for independence. Numeric variables were transformed when necessary and values presented are backtransformed least square means.

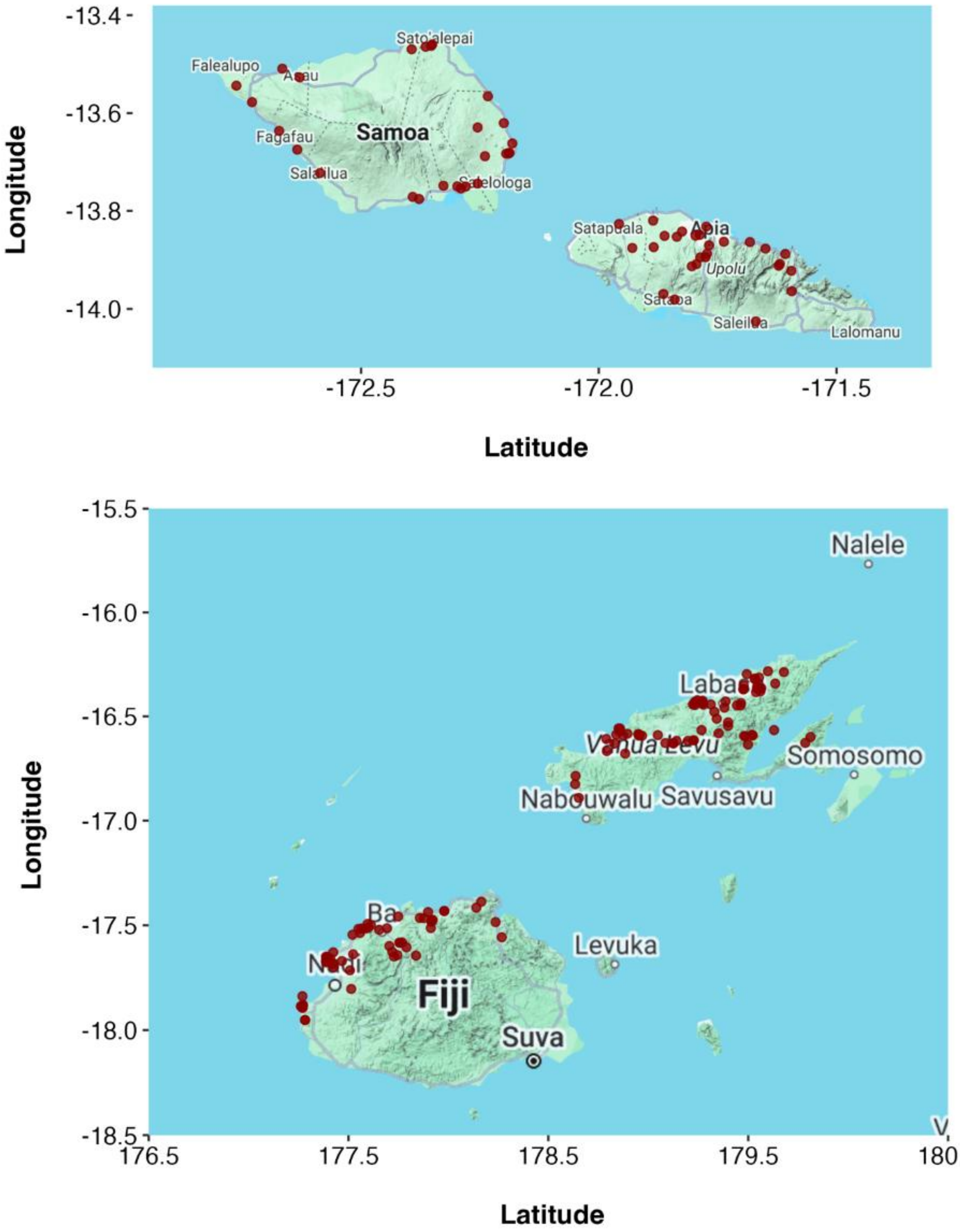

Figure 2: Locations in Samoa and Fiji where the baseline survey was conducted. In total 184 households (red dots) were surveyed across all regions.

5.4 On-farm monitoring program of sheep and goats in Fiji and Samoa.

In order to better understand the production characteristics of small ruminant farms in Fiji and Samoa the project established a monitoring program in these countries. The farms participating in this program were selected out of the list of farms in the baseline survey reported in Section 7.1. The program started in Feb and May of 2022 in Samoa and Fiji, respectively. When initiated in the program, a stocktake was conducted in order to enrol all small ruminant animals in each farm. This was done by ear tagging animals that were not tagged and recording the tag number, sex and category (i.e. adult or grower). In addition, farmers received a booklet (Appendix 1: Project booklet for on-farm monitoring) to record herd/flock information such as births, deaths, sales/gift/home consumption, rainfall, re-tagged animals and farm expenses. Farmers were also supplied with a hanging scale, rain gauge, eartags and training so they could continue the data recording process. Every month, project officers visited the enrolled farms in order to transfer the data recorded in the booklets into a data collection app developed using the CommCare as exemplified in Figure 3. In addition, all lambs/kids born during the project had their liveweight recorded every 3 months and stocktakes were conducted every 2 months. Some farms had to be discontinued of this program given the lack of adherence to the data collection process. In Fiji, the number of farms enrolled increased with time: 2 Goats and 1 Sheep farm in Western Division in May 2022; 4 Goats and 5 Sheep farms in Western Division in February 2023; 4 Goats and 3 Sheep farms in Northern Division in July 2023. In total, 19 farms were monitored in Fiji, being 10 goat and 9 sheep farms. In Samoa, the farms were enrolled as follows: 6 sheep farms in Upolu in February 2022; 5 farms in Savai'i in March 2022; 4 sheep farms in Savai'i and 5 sheep farms in Upolu in February 2023. The data collected was analysed in order to provide estimates of production parameters (e.g. liveweight gain, lambing/kidding rate, mortality rate, average sale price, average selling weight, etc.). For some analyses we could not utilize the data of all farms due to missing values or lack of consistency.

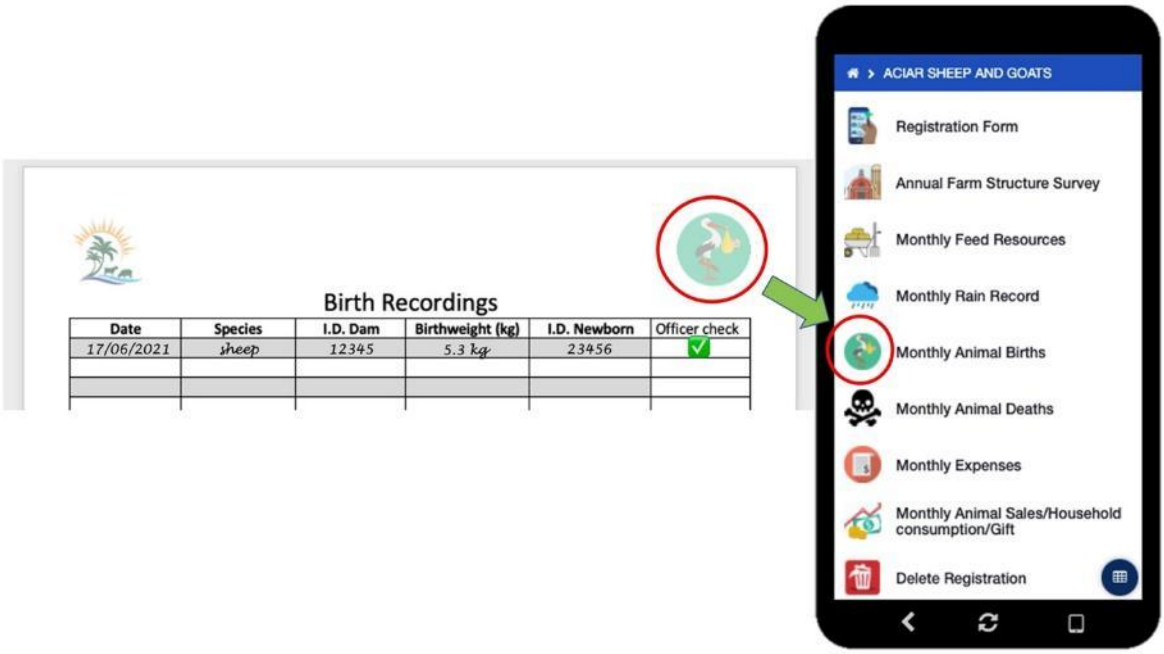

Figure 3: Representation of collection of on-farm information in project booklet by farmers, with support from project officers, who later transferred the data into the Commcare data collection app.

The productive parameters of each flock were calculated as follows:

Conception rate (%) = [number of ewes or does which gave birth within one year/ (number of ewes/does in the flock/herd at the start of the year - number of ewes/does that died or went missing)] x 100

Lambing / kidding rate (%) = [number of lambs or kids born within one year / (number of ewes/does in the flock/herd at the start of the year - number of ewes/does that died or went missing)] x 100

Litter size (n) = number of lambs or kids born within one year / number of ewes or does which gave birth within one year

Mortality rate (%) = number of adult females which were classified as dead within one year/ number of adult females in the flock/herd at the start of the year) x 100

Missing rate (%) = number of adult females which were classified as missing within one year/ number of adult females in the flock/herd at the start of the year) x 100

For each performance parameter the distribution of the data was compared across all farms in order to obtain the quantiles of distribution of the data. It was adopted that the target performance level to be equal or greater than the 75th percentile.

5.5 Anthelmintic resistance status of Fijian sheep and goat farms.

Farms selected to participate in this trial were previously interviewed during the baseline survey, which helped to select farms based on their flock/herd size and anthelmintic usage. Farms selected for this trial had not used any anthelmintic over the previous 60 days. Seven treatments were utilised in this trial: albendazole (ALB), levamisole (LEV), combination of LEV and ALB, ivermectin (IVM), moxidectin (MOX), closantel (CLO) and control (CON). Each treatment was tested in seven different flocks/herds varying from 6 to 10 animals per group. The average liveweight of selected animals was 25.2 $\pm$ 6.0 and 31.9 $\pm$ 8.8 kg, for goats and sheep respectively. The anthelminthic doses were selected based on the registration data for each product (typically for sheep) or dose rates suggested in the literature (typically for goats, as few anthelmintics are registered for use in goats, (Terrill *et al.* 2001; Dixit *et al.* 2019). Suggested dose rates for goats are often higher than for sheep because of a greater capacity of goats to metabolise and inactivate anthelmintics (Knox and Hunt 2014), and species differences in drug clearance rates of specific anthelmintics. All treatments were applied orally using a syringe (on day 1) with dosages being individually calculated for each animal based on liveweight. A summary of the groups and treatments utilised is provided in Table 1.

Table 1: Summary description of treatment distribution by host species and location, treatment group size per farm, average liveweight and utilised dosages of treatments included in the trial.

	Anthelmintic treatments						
	ALB[A]	LEV	ALB+LEV	IVM	MOX	CLO	CON
Number of farms (n)	7	7	7	7	7	7	11
Number of animals (n)	55	57	56	63	63	60	89
Farms by division (n)							
Northern	4	4	4	4	4	4	6
Western	3	3	3	3	3	3	5
Farms by species (n)							
Goat	4	4	4	4	4	4	6
Sheep	3	3	3	3	3	3	5
Group size per farm (n)							
Maximum	9	10	10	10	10	10	10
Minimum	7	7	7	7	7	7	6
Liveweight (kg ± sd)							
Goat	25.3 ± 7.0	23.0 ± 4.6	24.9 ± 6.5	24.6 ± 5.6	27.5 ± 6.1	25.1 ± 6.1	25.7 ± 5.8
Sheep	28.9 ± 7.7	31.3 ± 9.6	33.2 ± 8.2	32.5 ± 9.3	34.0 ± 8.8	31.6 ± 9.8	31.7 ± 8.4
Dosage (mg/kg)							
Goat	3.8	12	3.8 + 12.0	0.4	0.4	10.0	-
Sheep	3.8	6.5	3.8 + 6.5	0.2	0.2	7.5	-

Anthelminthics tested were: Albendazole (ALB); Levamisole (LEV); Ivermectin (IVM); Moxidectin (MOX); Closantel (CLO); Control (CON)

Individual faecal samples were collected directly from the rectum on days 0 and 14 and were used for conducting faecal egg counts (FEC) and larval differentiation. A modified McMaster technique was adopted for determining FEC and pooled larval samples were cultured for harvesting of larvae (L3) and identification of parasites genus. Data was stored, organized, and analysed in Microsoft® Office Excel using the RESO FECRT spreadsheet designed by Angus Cameron, AusVet Animal Health Services for the University of Sydney using the calculations described by Waller *et al.* (1989). The calculations were based on RESO FECRT program and on those published by Coles *et al.* (1992) with the modifications developed by Brown *et al.* (2001); Dobson *et al.* (2012). RESO results are for all GIN genus combined and included the mean FEC, the percent reduction in the mean count as well as the upper and lower 95% confidence interval (CI). Where the lower CI is less than 0, this value is not truncated to 0. The percent reduction in GIN eggs (FECRT%) was calculated by using the following equation (Coles *et al.* 1992):

$$FECR\ (\%) = 100x[1 - (\frac{T2}{C2})]$$

where T2 and C2 are arithmetic means (FEC) of the treated and control group on day 14.

The efficacy status of anthelmintics was interpreted based on the WAAVP guidelines (Coles *et al.* 1992) where resistance is present if (i) FECR is less than 95% and (ii) the lower 95% confidence interval (CI) less than 90%. When only one of the previous criteria's was met resistance was suspected. If none of the criteria is met the herd or flock was classified as susceptible.

5.6 The production impact of ineffective gastrointestinal nematode control in Fijians small ruminant systems.

Small ruminants (i.e. sheep and goats) have crucial economic and social importance in Fijian society however domestic production is currently far from able to support local demand (Cowley *et al.* 2019). Ineffective control of gastrointestinal nematodes is suggested, amongst others, as one of the main factors restricting higher production levels (Cowley *et al.* 2019). However, its unknown the degree to which this factor is restricting productivity. Gastrointestinal nematodes parasitism has been demonstrated to affect small ruminant production reducing liveweight gain, milk yield and wool growth. The degree which parasitism affects production will vary accordantly to each production system, but its quantification is important in order to determine the impact and the economic return of control practices.

The production impact of ineffective gastrointestinal nematodes control was investigated in the Western (n=12) and Northern (n=7) Division in Fiji in sheep (n=9) and goat (n=10) farms. In each farm, 15 head or 20% of the total flock/herd (whichever was smaller) was randomly selected and treated every 3 months an effective GIN treatment (i.e. albendazole capsule (2.3 g capsule for 20 to 40 kg LW) and injectable cydectin (1 mg/kg LW)). The same number of reproductive females was also randomly assigned as the Control group which received the normal anthelmintic treatment of the farm and grazed together with the treated group. The trial was initiated in May 2022 and data collected until December 2023. Liveweight, body condition score (BCS) and FAMACHA score were assessed every three months. Faecal samples were collected every two months for determination of faecal egg count (FEC) by a modified McMaster technique, using 2 g of faeces mixed with 28ml of saturated salt solution, with a detection limit of 100 eggs per gram of faeces (epg). The statistical analysis of the results were conducted using the software R (R Core Team 2019) and the linear mixed effects model models (*lmer*) within the package lme4. The statistical models included treatment and small ruminant specie as fixed factors and animal ID within farm ID as random factor.

5.7 The effect of long-acting drenches on peri-parturient ewes and does as well as on their offspring on Fijian Research Station

This experiment was to compare different types of long-acting drenches: Cydectin LA (20g/L injectable moxidectin) and Extender Junior (2.3g albendazole capsule), and their effects on minimising gastrointestinal nematodes in peri-parturient ewes and does. The experiment consisted of two separate trials which were conducted using the same treatments and design. The first experiment was conducted at Nawaicoba Quarantine Station with sheep and the second experiment at Sigatoka Research Station with goats. In both trials treatments were administered at the beginning of July with the following combinations: Cydectin long acting (MOX), Extender Junior (ALB), MOX + ALB and Control (untreated) group. All treatment groups were composed by 15 reproductive females that have been joined during the previous joining season. All treatment groups grazed together the same paddocks until the end of the trial. Ewes gave birth in August while does birth dates were spread between the end of July (27/07/2022) and early September (06/09/2022). The outcome variables in this trial were faecal egg count (FEC), liveweight, body condition score (BCS) and FAMACHA score of reproductive females as well as birth weight of lambs and kids. Data was analysed with a linear mixed model for the fixed effect of treatment, species and dates and used the animal ID as a random factor. The kidding and lambing rate was analysed by a logistic regression including treatment and species as explanatory variables.

5.8 Field test of creep-feeding supplementation on lamb performances at Nawaicoba Quarantine Station.

Lambing during dry periods is certainly a challenge as ewes have to obtain the necessary nutrient requirements from low quantity and quality pastures. Ewes often lamb in low fat condition score leading to low milk production, which restricts lamb growth. This situation leads to lower survival rates and weaning weights of lambs. This field test was conducted at Nawaicoba Research Station with a mob of 200 ewes. This mob was expected to lamb from July to October 2022. The mob was drafted in July into two different groups based on ewe's live-weight (LW) and expected lambing date. Ewes started lambing after being separated into the two different groups and continued grazing in separate paddocks from lambing to weaning. Group 1 (control; n = 77) received the standard management protocol of the farm while Group 2 (Creep; n = 65) also received the standard management protocol but its lambs also had access to creep-feeding supplementation. The creep-feeding supplement was offered at a rate of 2% LW of lambs from birth to weaning. All lambs were weaned after 90 days from the beginning of the trial. The composition of supplement offered to lambs was crushed wheat (60%), soybean meal (34%), lime (1%) and molasses (5%). The supplement refusals were collected weekly, weighed and dried in order to obtain the dry matter content and average weekly intake for the group.

5.9 Growth performance and puberty attainment of replacement ewes supplemented post-weaning.

The experiment was conducted at Nawaicoba Quarantine Station and utilised 100 lambs born in July 2023 which were single born daughters of Fiji Fantastic ewes crossed with Fiji Fantastic (FF; n = 50) or White dorper rams (F1; n = 50). Lambs were weaned on the 17th of October with an average liveweight and age of 20.9 kg ± 2, 116.6 ± 7 days and 20.8 kg ± 1.9 and 117.0 ± 7 days of age for F1 and FF groups respectively. After weaning, the lambs were separate into two groups (Control and Treatment) balanced for age, liveweight and genotype. The Control group received the standard management practice of the farm (i.e. access to mineral supplementation blocks) while the treatment group was supplemented with concentrate. Each group rotationally grazed 4 paddocks of Koronivia grass (*Urochloa humidicola*) which were switched at the end of each grazing period (28 days) in order to minimize any possible paddock effect. Each group of 50 lambs had access to a group of paddocks (n = 4) with a total area of 5.7 or 5.9 ha. The supplement provided to the Treatment group was composed of wheat (60%), soybean meal (30%), lime (5%) and molasses (5%). All animals were weighed, had BCS and FAMACHA score recorded every 2 weeks. The two different groups were merged and exposed to teaser rams between the 4th of May until the 14th of June. During this period the ewes which presented heat signs were recorded and data was analysed in order to investigate the effect of supplementation on puberty attainment.

5.10 An agronomic assessment of two cultivars of Juncao grass compared to Guatemala and Elephant grass in a tropical environment: the effect of pre-harvest canopy height on yield and nutritive value.

Juncao grass (*Cenchrus fungigraminus*) is a recently developed C_4 fodder which has been introduced to several developing countries supported by different aid programs. However, there is currently a lack of field studies to support the development of management recommendations that can be adopted by farmers. This research aimed to compare two cultivars of Juncao to Guatemala and Elephant grass in relation to biomass production and nutritive value subjected to different harvest frequencies. The study was established at Sigatoka Research Station in a split-plot design with 4 pre-harvesting target canopy heights (0.5, 1.0, 1.5 and 2.0 m) as the main plots and the 4 fodder species/cultivars as the subplots. Canopy height was measured at 30 different points in each subplot at least once a week, using a 2.5 m ruler equipped with a round rising plate (90 cm of diameter and 600 g of weight). The plots were harvested once the canopy height reached ± 10% of its target harvesting height. Fodder sub-samples were dried in a forced oven for 72h at 65°C (0100FD, Thermoline Scientific, Sydney, Australia) and ground to 1mm using a hammer mill (C & N Laboratory Mill, Christy & Norris Ltd., Chelmsford, England). Sub-samples were then stored at ambient temperature in plastic zip-lock bags until analysis. Chemical analyses were conducted by Cumberland Valley Analytical Services Laboratory located in Waynesboro, Pennsylvania, USA. All data analysis was conducted using the open software R version 4.1.2 (R Core Team 2019). Prior to the analyses all variables were visually checked for normality and homoscedasticity of variance and models were developed utilizing generalized linear mixed models with the '*lme4*' package (Bates *et al.* 2015).

5.11 Inventory of local feed resources for livestock feeding in Fiji: availability, nutritional composition and value chain perspectives.

Livestock performance in tropics is seriously affected by seasonal deficiencies in feed supply due to seasonal weather patterns. There is need for identification of the timing and nature of feed gaps so that farmers can make informed decisions regarding selection of supplementary feed resources to reduce the risk of feed shortages during different seasons affecting the animal performance and production cycle. The research aimed to assess the feed resources and feeding practices on small ruminant (SR) farms in Fiji and identify their availability, nutritional compositions and how they can be integrated into feeding and supplementation strategies. The descriptive survey on common feed resources used on small ruminant farms was carried out in the major sheep and goat producing provinces (Bua, Macuata, Ba and Ra; Table 2) which are located on two main islands of Fiji, Viti Levu and Vanua Levu. A total of 85 structured quantitative and qualitative questionnaires were developed on kobo toolbox app which is an open-source software package. Due to national COVID-19 restrictions in Fiji, the survey was conducted via telephone and the responses given by farmers were entered into the handheld tablets simultaneously. Pre-test of the survey questionnaires on Kobo toolbox app were conducted on few farms (n=12) as part of initial training and testing to fix glitches and train the project officers. Surveys were conducted in Hindi and Fijian languages depending on the ethnicity of the farmer. Progressive data collection work was conducted from 7th of Dec 2021 to 4th of Jan 2022.

Table 2: Total number and percentage of farms interviewed by provinces of Fiji.

Province	Number of farms (n)	Proportion (%)
Macuata	63	25.4
Bua	63	25.4
Ba	62	25
Ra	60	24.2
Total	**248**	**100**

5.12 Investigating local consumer attitudes, habits, and preferences for sheep meat in Samoa.

The demand for sheep meat in Samoa is mainly met by imports which are high in fat content and one of the contributing factors to non-communicable disease and related health issues (Thow et al., 2014). To reduce the reliance on imported meat products, the government of Samoa introduced the first sheep flock in the country in 2004 (Government of Samoa, 2014). Although the sheep population has gradually increased, local demand and consumption of sheep meat are still dominated by imported sheep meat (Davies, 2019). This study aimed to evaluate consumer attitudes, preferences, and factors influencing consumer habits towards sheep meat and identify strategies to promote the marketing of local sheep in Samoa. The study was conducted on the islands of Savaii and Upolu through face-to-face interviews. Due to the limited information available on sheep meat in Samoa, there was a need to investigate the status of sheep meat availability in the country, both imported and local. The target audience consisted of ten local sheep farmers, ten distributors, and a hundred (100) consumers. Farmers were asked about their opinion on sheep meat characteristics that may draw consumer and market attention. Distributors were asked about their opinion on local sheep meat and any opportunity for their business to sell local meat and ways they thought could be used to promote and market local sheep meat in Samoa. The information gathered from farmers and distributors was then used to develop a questionnaire for consumers, to determine the attributes, and their levels, that would most likely influence consumers' decisions to buy sheep meat. Questionnaires were designed to collect qualitative and quantitative data to answer the objectives. The data collected were analysed with frequency analysis using IBM SPSS Statistics Version 28.0.1.0.

5.13 Gross margin analysis of small ruminant production in Fiji

The analytical framework used in this study was gross margin analysis that focuses on assessing financial performance of an agricultural enterprise in the short term. Gross margin (GM) is defined as total revenues minus total variable costs of production. If GM is positive, it means that the enterprise (goats or sheep) has generated enough revenues not only to cover all variable costs, but also is able to recover some portion of the fixed costs. If the GM is negative, it means the enterprise has not generated enough revenues to cover even the variable costs, and the business will be better off, and money can be saved, by shutting down the operation. In economics, the point where total revenues equal total variable costs (ie when gross margin is zero) is known as the shutdown point. A related economic concept is breakeven when total revenue equals total cost of production. Breakeven price per kg is calculated by dividing total costs by total live weight produced. The payback period can also be determined by dividing total fixed or investment costs by GM.

Costs of production (both variable and fixed costs) considered in the GMA pertaining to a SR enterprise in Fiji is summarised in Table 3.

Table 3: Variable and fixed costs identified in small ruminant production in Fiji.

Variable costs	Fixed costs
• Breeding: purchase of replacement stock. • Feeding: feeds and protein supplements, salt/mineral, and other supplements. • Animal health: drenching, vaccination, vet medicine and services, vet supplies. • Marketing: transport/communication. • Running costs of machinery: fuel, electricity, oil/lubricant. • Repairs and maintenance of machinery, animal housing/shed and fences. • Labour: casual and family labour. • Pasture maintenance: seeds, planting materials, fertiliser, herbicides, irrigation.	• Breeding stock. • Land/rental. • Animal housing/shed. • Fencing. • Machinery: tractors, implements, bulldozers, trucks, vehicles, motorbikes. • Farming equipment/tools • Generator, pump, water tanks, pipes. • Establishment of improved pasture. • Overhead: office, office supplies, salaried personnel. • Annualised fixed costs, in the form of: depreciation; interest; Insurance; taxes.

Interviews with farmers with different production systems and in different locations were conducted on several occasions to understand the farm set up and the operating environment and to collect the data required for GMA, mainly production parameters, sources of revenues and costs of production. Altogether around 20 different farms were visited; some were visited more than once so that data that were previously collected could be verified. Those farmers were also participants of the on-farm monitoring program/drenching trials. This overlap has enabled us to triangulate and cross-check the data we have collected from separate farmer interviews. Training workshops were conducted separately for MoA research and extension staff and project officers, and for farmers. The objectives of the training were to: (1) raise awareness of the need for farmers to become more business-minded and market- oriented as they transition from subsistence farming to semi-commercial/commercial farming; (2) help better understand the costs and returns from goats/sheep farming, and the importance of record keeping; and (3) demonstrate the GM impact of adopting more appropriate production and marketing practices using a GM calculator. The training on farm economics were followed by group discussions whereby participants, divided into small groupings, were asked to do the following:

- Identify major activities associated with SR farming, including the routine activities that are done every day, and those that are done only occasionally or where required.
- Identify the inputs required to implement those activities.
- Estimate the costs or expenses associated with those inputs used.
- Calculate GM.
- Estimate the cost of production per kilogram and compare that with sale prices.

The steps included in the group discussions are in fact an on-farm application of the value chain analysis proposed by Porter (1985). The essence of the value chain analysis was to break down an enterprise into a set of primary and supportive activities. These activities were then costed to assess their impact on profitability, as well as to identify issues and areas for improvement.

More than 20 interviews were conducted in the Western and Central Divisions with traders, middlemen, wholesalers, Fiji Meat Industry Board (FMIB), butchers, supermarkets, and hotels/restaurants. The objectives were to characterise the animal traits of SR that are preferred by buyers in the formal market and to identify potential market segments. In addition, we consulted widely with agricultural officers and meat inspectors of MoA, as well as researchers who were involved in the EU-funded value chain project and ACIAR-funded sectoral analysis of the SR sector. Interview questions focused on: sales volumes, the types of animals they buy, their suppliers, and their customers and what they like to buy, as well as any problems they have encountered in running their business. The market survey focused on goats simply because it soon became clear that few or no local sheep were sold through the formal market as it is occupied by imports, and local sheep were sold through the informal market alone.

6 Achievements against activities and outputs/milestones

Objective 1. Assess the productivity of current production systems, and understand the costs, benefits and motivations for men and women farmers to make improvements.

no.	activity	outputs/ milestones/completion dates	comments
1.1	Develop and test a social inclusion (SI) strategy that enables participation of disadvantaged groups, including women and youth	Key informant interviews to inform social inclusion strategy (2021 Dec - Completed). Field officers and other project partners trained in facilitating FGDs and participatory appraisal methods (2022 Jan - Completed). Focus groups with SR farmers, targeting women to identify gender and social issues, and participation, decision-making, and distribution of benefits of SR production to men and women farmers, as well as local information networks on extension needs from a gendered point of view (2022 Jan/Apr – Completed) Finalised SI analysis and strategy for on-going representative qualitative research (2022 Feb – Completed). Training provided to project partners on socially inclusive extension and research approaches (2022 Jan Feb – Completed) Survey Report on participation, decision-making and engagement in and among SR farming households throughout the project (2024 Apr – Completed)	Key informants' interviews were conducted with representatives experts, including government and non-government extensionists, farmers and independent consultants, within the goat and sheep sector in Fiji. Project officers and MOA partners received training in Gender equality & Social Inclusion by Anna Cowley in March 2022 before the start of series of FGD's conducted as part of the GESI strategy. A total of 9 FGD's were conducted (5 in Viti Levu and 4 in Vanua Levu) between March and April 2022 by Flavia Ciribello and Roshika Deo. In total 93 sheep and goat farmers participate in the FGD which included 61 women farmers. Ad-hoc validation workshops were organized and delivered via community-based discussions reaching out to a total of 117 farmers (73 women)[1]. The validation workshops served as an opportunity to not only verify the preliminary findings from the FGDs but also provide technical training to farmers. This training was delivered by the project staff, allowing for an important follow-up on the initial findings raised during the FGDs. The findings and insights from the FGDs were shared with the project staff, as well as with the Ministry of Agriculture in Fiji and Samoa, during dedicated capacity building workshops and discussions. The data and information collected were analysed to develop well-informed project recommendations. Reports summarizing the findings, learnings, and recommendations from the FGDs in both Samoa and Fiji were prepared. A summary of these reports was presented during the Project General Meeting, which took place in June 2023.

[1] The validation workshop were organized in 5 project locations in Fiji involving 71 farmers (56 women/25 men), and in 2 project location in Samoa involving 46 farmers (17 women/29 men).

1.2	Conduct a participatory situation analysis of current production systems and livelihoods	Recruited project junior field officers set up to monitor sites (Completed) 5 enrolled SR farmers at each site (Completed) Quantitative benchmarking report on initial status of current production systems and opportunities (Completed – 2022 to 2024) Additional farmers enrolled (2022-2024 – Completed)	Six project officers were recruited and trained to conduct the project activities in Fiji and Samoa. They are Toya Areta and Zac Sui'a in Samoa and Divesh Prasad (Western Division Fiji), Alice Baleiverata (Western Division Fiji), Ritesh Rao (Northern Division Fiji) and Shayna Mala (Northern Division Fiji). Baseline survey collected data on farms in Samoa (n = 53) and Fiji (n=131). Preliminary analysis of the data was presented at the 34th Australian Association of Animal Science conference by the project officer Toya Areta. The number of farms enrolled increased with time following the given schedule in Fiji: 2 Goats and 1 Sheep farm in West in May 2022; 4 Goats and 5 Sheep farms in West in February 2023; 4 Goats and 3 Sheep farms in North in July 2023. In total, 19 farms were monitored in Fiji been 10 goat and 9 sheep farms. In Samoa, there were a total of 20 farms enrolled as follows: 6 sheep farms in Upolu in February 2022; 5 farms in Savai'i in March 2022; 4 sheep farms in Savai'i and 5 sheep farms in Upolu in February 2023. During the on-farm monitoring program we have individually recorded information of a total of 3,809 animals being 718 sheep in Samoa, 1,421 sheep in Fiji and 1,670 goats in Fiji.

1.3	Participatory design, agreement and review of interventions and capacity building strategy	Inception workshop and Annual planning meeting (Completed) Capacity building and training strategy and program (2022 Jan - Completed) Establishment of local SR farmer interest groups at project sites and FGD on project interventions (2022 Jan - Completed) Project planning meeting with work plans & responsibilities agreed (Oct 2021 - Completed) Farmer engagement on research plans and designs for project interventions eg, practicalities, which forages, what drenching practices etc (Throughout project as on-farm interventions are trialled – Completed) Annual planning meeting (2022 Jul - Completed) Mid-term Review workshop (2021 Jun – Completed) Annual planning meeting and Capacity building strategy evaluation (2023 Jun - Completed) Annual planning meeting (2024 Jan – Completed) Final Project Review (2024 Jun – Completed)	A project inception workshop was held with stakeholders from Fiji and Samoa to interpret and plan how to address the project objectives. Shortly after recruitment, project officers received a one week training program that covered the overall objectives and milestones of the project. In addition, the officers were introduced to new tools and methods that were applied during the project activities (e.g. faecal sample collection, CommCare data collection system, project booklet). Farmers enrolled in the on-farm monitoring program received all necessary equipment (e.g. scales, eartags, rain gauge, project booklet) and training to start data recording on farm. In addition, farmers received a project assessment form. The form was designed to collect in an unidentified manner the suggestions and complaints from farmers on how the project can improve. In June 2023 a project meeting was conducted in Rakiraki (Fiji) which included the participation of Fijian Ministry of Agriculture staff, Samoan Ministry of Agriculture staff, project officers, participating farmers and higher research degree students. During the meeting, it was presented the results obtained through the different activities of the project and it was discussed what points and/or activities could be improved. The participants also had the opportunity to visit some project farms and discuss the progress of the project directly with participating farmers. This was probably the most valuable meeting conducted throughout the project.
1.4	Evaluate past SR research in Fiji in light of uptake, adoption and persistence of technologies	A report on the successful adoption, extension and persistence (or otherwise) of previous research SR research in Fiji and the factors affecting success (2021 Oct – Completed)	A literature review on the successful adoption, extension and persistence of previous research has been completed by Dr. Romana Roschinsky. In addition, interviews were conducted with current and past Fiji Ministry staff to better understand the reasons off the not application or discontinuity of each management practice. The findings of the literature review and interviews were consolidated in a final report (Appendix 2: A Review of small ruminant research in Fiji and Samoa.). Preliminary findings have been published by Dr. Romana Roschinsky and presented at Tropentag Conference 2024.

1.5	Understand the current feed calendar in SR producing areas of Fiji and Samoa	Feed availability report for SR producing areas of Fiji and Samoa (2022 Dec – Completed)	This objective was achieved by Ronil Prasad who is a staff member of Fijian Ministry of Agriculture. It consisted of a survey (n = 248 farmers) conducted to identify the main feed sources and supplements used by farmers in the Northern and Western Division of Fiji. A summary of its findings was presented by Mr. Ronil during the 34th Australian Association of Animal Science conference, and the research contributed to his Masters thesis.
1.6	Identify current extent, timing and causes of lamb/kid losses on smallholder and semi commercial farms	Benchmarking[2] report of current and potential reproductive productivity identifying extent and timing of young stock losses. Initial report showing seasonal variation (2022 Dec – Completed) Published journal paper showing year-to-year variation (2024 Jun - ongoing)	The quantification and identification of causes and timing of the losses have been conducted as part of the project on-farm monitoring program. The information on the losses was continuously collected and from Feb 2022 until June 2024. Preliminary reports were presented during the Annual meeting in Rakiraki in 2023 as well as during the End of Project Review meeting in Labasa and Apia in March 2024. A peer review paper is currently in preparation reporting on the productive parameters measured on-farm in Fiji and Samoa.
1.7	Monitor cost and value of production (including labour), income and benefits from current and improved sheep and goat production	Train MoA and MAF staff in value chain interviews (2020 Jun - Completed) Target markets and animal traits for SR animals characterised (2023 Dec- Completed) A cost of production and gross margin calculator (2023 Jul - Completed). Socio-economic data collected on other, non-SR enterprises on enrolled SR farms (2024 Jan- Completed) Training/workshop for extension staff on GM impacts of production systems (inputs, market destinations, lost production). (2023 Jul - Completed) End of project survey of costs and income from SR production (2024 Jun). A manuscript for peer-reviewed publication on the contributions of SR enterprises to whole farm incomes (under current and improved production systems); and evaluation of how innovations impact on farm profitability (2024 Jun)	A value chain analysis focussing on understanding buyers' quality requirements for sheep and goats has been completed for Fiji and Samoa, in addition to a Masters thesis on the VC in Samoa that has been submitted for examination (Tusiata Lemuelu, USP). Results show that demand for locally produced live small ruminants is high because they were perceived to be more natural and healthier (less fatty) than imported products. However, there were severe supply shortages of local stock in both countries, especially to the formal market. As a consequence, quality was not the main issue facing the buyers, but the lack of supply. The team is addressing the supply issue with relevant research (worm control, supplementary feeding, pasture management, etc). Gross Margin Analysis (GMA) training has been completed in Fiji and Samoa. Monitoring farm data collected in Samoa, including incorporation of data from the Samoa Ministry of Agriculture flocks.

[2] Benchmark: A description of the current situation to be used as a point of reference for comparison with innovations and interventions

1.8	Monitor the environmental impacts of small ruminant production systems	Incomplete	This activity was discontinued after discussions during the Mid Term Review. It was agreed that given the delays caused by COVID-19 restrictions, it would be more advantageous to focus on activities with higher priority.

PC = partner country, A = Australia

Objective 2. Test innovations to improve husbandry and feeding systems so as to better manage feed gaps, reduce mortality and improve small ruminant turn-off rates in Fiji and Samoa

no.	activity	outputs/ milestones/completion dates	comments
2.1	Participatory evaluation of technology packages trialled in Objectives 2 & 3 to improve productivity and livelihoods, and dissemination and adoptability of trial results	Field officers and project partners trained in digital data collection, condition scoring, WEC, syndromic health assessments (2021 Dec - Completed) Farmers trained in use and application flock recording and monitoring (eg condition scoring) (2022 Jul - Completed) Quantitative measures of year-to-year variation in productivity and husbandry practice (2024 Jun – Completed) Farmer discussion/feedback on research plans and feasibility/acceptability of potential tested interventions (2024 Jun - Completed) Recommendations of different technology bundles accounting for their suitability to: different household and farmer constraints, costs/benefits, and adoptability: (2024 Jun - Completed)	All project officers and ministry staff from Samoa and Fiji received initial training on data collection, grazing management, body condition scoring, FAMACHA scoring, faecal egg count and larval differentiation methodology. In addition, additional training has been conducted on small ruminant parasitology (March 2023), Gross margin analysis (June 2023) and overall husbandry practices for small ruminants (November 2022). Feedback from farmers on research plans and possible interventions were continuously stimulated by project officers during the monthly visits. We have noticed that farmers were more comfortable in sharing their ideas and aspirations given the relationship built with project officers. All enrolled farmers in the on-farm monitoring program (n = 39; across Fiji and Samoa) were trained to do flock recording using the project booklet as well as assessments such as body condition score and FAMACHA.

2.2	Trial the use of fodder banks of improved forages and assess how they can be used for strategic supplementation of key stock classes, and reduce the impact of feed gaps	Distribution sites of suitable improved feed resources (eg forage tree legumes, grasses, herbaceous legumes) for distribution to enrolled farmers (2022 Jul – Completed). Farmers trained in fodder establishment and agronomy (2023 Jan - Completed). Fodder banks of improved forages established (2023 Jul) Recommendations of potential fodders to fill dry season feed gap (2023 Ju - Completed) Field day for farmers at research station sites incorporating farmer discussion group and feedback on farmer perceptions, interest and barriers of utilising forages (2024 Jun) Identification of next steps in research to overcome adoption barriers to improving plane of nutrition for SR (2023 Dec - Completed) Recommendations on strategies which fill the dry season feed gap and are practical, adoptable and return a benefit to farmer livelihoods (2024 Jun - Completed)	Given the results obtained by the research trial conducted at Sigatoka research station which evaluated the harvesting frequency of four different types of tropical forage, farmers were informed about the results and given the option to start planting these forages in their properties with project support. A program to support farmers to established improved pastures in their properties was conducted in partnership with Fijian Ministry of Agriculture. Pasture planting material of leucaena plants which were produced by Sigatoka Research Station were distributed to farmers in the North and Western Division. In addition, we developed a leaflet guide on implementation and utilisation of these areas (Appendix 3: Guidelines: Planting and utilization of leucaena and koronivia pastures.).
2.3	Trial the use of creep supplementary feeding of locally available feeds and forages to lambs and kids	Assessment of feed resources suitable and acceptable for creep feeding (March 2022 - Completed). Recommendations of creep feeding interventions which can increase kid survival and growth (2024 Jun - Completed). Farmer field day demonstration of use of creep feeding at experimental site (2023 Jul) Recommendations of creep feeding interventions which can increase doe condition score and lambing rate (2024 Jun - Completed). Farmers trained in implementation of creep feeding of lambs/kids (2023 Jun - Completed) Recommendations of creep feeding interventions which are practical, adoptable and return a benefit to farmer livelihoods (2024 Jun - Completed) Manuscript for peer-review publication on the effect of creep feeding on lamb/kids (2024 Jun – In progress) Advisors/extension staff trained in creep feeding technologies (2024 Jun - Completed)	The effect of creep-feeding on lamb's growth rate and survival was conducted at Nawaicoba Research station. The results showed a large benefit in utilizing this type of supplementation for lambs in both animal and economic performance. Given these results, a new trial was conducted during the last project year (2023-2024). This research was also conducted at Nawaicoba Research station and investigated the effect of post-weaning supplementation on growth and reproductive performance of replacement ewe-lambs. The results of the creep feeding trial were published and presented by Mr. Mohammed Hazeem and Salesh Chandra (MoA staff) during the 8th Pacific Agriculture and Forestry Regional meeting held in Nadi in 2023.

2.4	Assess the effects of different flock structures on productivity and enterprise gross margins	Completed (June - 2024)	The effect of different productivity levels on GMA was assessed for Fiji sheep and goat farms. Full report is provided in Appendix 4: Gross margin analysis of small ruminant production in Fiji.

PC = partner country, A = Australia

Objective 3: Evaluate the effectiveness of current worm control strategies in Fiji and Samoa, and develop options for improving worm control and use of anthelminthics

no.	activity	outputs/ milestones/completion dates	comments
3.1	Estimate effectiveness of current parasite reduction strategies and practices and their contribution to anthelmintic resistance on smallholder and semi-commercial farms	Research staff able to sample and analyse faecal WEC (completed) A report on current practices, and their implementation (2023 Jun - Completed) A report on the effectiveness of current worm control practices, on prevalence of and practices contributing to anthelmintic resistance on smallholder and semi-commercial farms (2023 Jul - Completed) Farmer group training on practices promoting/preventing development of drench resistance (2023 Dec - Completed) A report or policy briefing on opportunities and barriers to the importation of new generation anthelminthics in Fiji and Samoa (2023 Jul - Completed)	Multiple trainings on parasitology lab techniques and field identification have been conducted for both project officers as well as ministry staff from Fiji and Samoa. In addition, three parasitology labs have been set up (Lautoka, Labasa and Apia) and are now able to process samples from project farmers as well as samples submitted by external farmers. A peer-reviewed publication on the current situation on the anthelmintic resistance status of commercial farms in Fiji has been submitted for publication by Journal of Small Ruminant Research, based on the research conducted. In addition, another report on the barriers and opportunities for facilitating the commercialization of anthelmintics in Fiji has been written and delivered to MOA.
3.2	Estimate impact of worms on lost productivity in smallholder and semi commercial farms in Fiji and Samoa	A manuscript for peer-reviewed publication on the impact that worms have on the growth and reproduction of SR on Fijian and Samoan farms and providing evidence to farmers of the potential benefits of controlling worms (2024 Sept - completed) Results of cost of parasitism presented to farmers, and farmer discussion of costs and benefits of managing worms (2023 Dec - Completed).	The impact of inefficient worm control on farms was assessed in 19 farms across Fiji. This trial initiated in June 2022 and finalized in June 2024. The assessment of the main variables for a long period of time was necessary to capture the effect of treatment on reproductive, growth and mortality parameters. The results showed that females treated to be “free of worms” showed higher liveweight, body condition and FAMACHA score compared to control group. These differences however were biologically small and did not translate into higher reproductive efficiency or performance of their offspring.

3.3	Evaluate the effect of improved drench decision-making and use on worm burdens, animal production and on-farm adoptability	Evidence for improved anthelminthic efficacy of combination drenches or drenches which have not previously been used in Fiji, above that achieved with the present suite of drench families (2024 Jun - Completed). Farmers and advisors trained in FAMACHA and other approaches to identifying when and which stock to drench (2022 Jun - Completed) Farmer decision support systems for drenching (when, which animals, which drenches) that incorporate socio-economic factors and will reduce cost of production, improve animal productivity and minimise drench resistance (2023 Jan - Completed)	A large trial was set up in 12 commercial farms in Fiji to test the current drench efficacy of 6 drench treatments in sheep and goats. The results have been compiled into a report which describes the current anthelmintic resistance situation and recommendations on how to better overcome the current constraints. The full report is available at Appendix 5: Resistance status of six anthelmintic treatments in Fijian sheep and goat farms. In addition, a companion report was produced which reviewed the current policies and regulations of anthelmintic approvals and distribution in Fiji which was submitted to the Ministry of Agriculture. The full report is available at Appendix 6: Review of Ministry of Agriculture policies and regulations pertaining to small ruminant anthelmintic approval and distribution.
3.4	Participatory appraisal of potential for non-chemotherapeutic worm control strategies	Incomplete	This activity was discontinued after discussions during the Mid Term Review. It was agreed that given the delays caused by COVID-19 restrictions, it would be more advantageous to focus on activities with higher priority.

7 Key results and discussion

7.1 Review of small ruminant research in Fiji and Samoa

In general, there have been four major driving forces funding and conducting small ruminant research in Fiji: 1) the Ministries of Agriculture 2) internationally and nationally funded research and development projects and 3) Universities in Fiji and Samoa and 4) the Pacific Community (SPC). Of the two countries analysed the majority of small ruminant research has been conducted in Fiji with its longer history of keeping small ruminants. Small ruminant research activities in Fiji and Samoa have focused on 1) breeding, 2) health (mainly parasites), 3) feeding and nutrition (including forages), 4) husbandry and 5) other research. The amount of research on small ruminants varied greatly over time and was often advanced by individual researchers. A lot of early research results are no longer accessible.

A number of small ruminant technologies have persisted over time in Fiji including basic husbandry technologies like animal housing, the use of crossbreeding, the Fiji Fantastic sheep breed, the recommendation of a variety of technologies to manage gastro-intestinal parasites with a strong focus on chemical drenches, the introduction of improved forages, and the support via subsidised production inputs to small ruminant farmers.

Factors fostering the adoption of small ruminant technologies are diverse including good working relationships between farmers and extension staff, technology benefits which are easily observable, farmer-oriented extension delivery and the inclusion of farmers in governmental support schemes. A number of factors constrain the adoption or continued use of small ruminant technologies. Among the most prevalent factors are old age of the farming population, limited capital means for investment, labour or cost intensive technologies, traditional mindsets, insufficient supply of replacement animals, the land lease system, production issues and limited resources and time for extension staff training.

The results of this literature review show that the challenges of Fijian, and to a similar degree Samoan, small ruminant farmers are still very similar to those of early sheep farmers in Fiji (Manueli 2013): poor nutrition, internal parasites, theft, dog attacks and high investment costs. Walkden-Brown (1984) identified needs for the small ruminant sector that are still valid today: a stronger extension system, increased access to animal health products, accurate production information, access to subsidised breeding stock and fencing materials as well as assistance for farmers to access animals and materials. The growth and expansion of the small ruminant sector in Fiji and Samoa are carried by political will and a growing interest of farmers looking for diversified production options. Investments in further research activities regarding the development of integrated, farmer needs-centred small ruminant systems can only be recommended.

7.2 PSGIP – Gender equality and social inclusion

7.2.1 The importance of small ruminant farming for Fijian and Samoan families

In both Fiji and Samoa, the FGDs highlighted significant factors for women farmers, and their family, to be involved in the SR sector. In Fiji, the sector holds significant economic and socio-cultural importance, having supported families' food consumption and livelihood activities for generations, particularly among the Indo-Fijian communities. Goat and sheep farming emerged as a crucial source of income for farmers in Fiji, enabling them to fulfil basic family needs such as purchasing groceries, medicine, paying bills, and school fees. Additionally, goat and sheep farming also contribute to local food consumption, providing farmers with fresh meat while imported meat is primarily sold in supermarkets. Farmers also recognized traditional and religious practices involving the use of goats and their products, although some of these practices were more prevalent in the past than they are now.

The sheep farming is a relatively recent addition to the agricultural sector in Samoa, which is reflected in families' practices and involvement in the industry. As a result of the novelty of sheep farming in Samoa, the sector plays a less significant role, albeit one that is increasing, for most of the farmers interviewed, who are mainly considered *hobby* farmers. Providing food security for family; ensuring income; cleaning grounds and lawns of weeds; producing good fertilizer for crops; reducing imports of sheep meat are among the reasons motivating farmers in the sector. It’s also worth mentioning that few farmers noted the increasing use of sheep for fa’alavelave (cultural gifting events). Cows and pigs have been always the traditional food used for fa’alavelave, and this was highlighted as one of the factors limiting the expansion of the related formal businesses. Conversely, sheep are still not commonly used for fa’alavelave. This could be a matter of consideration for facilitating or limiting the future expansion of the formal businesses.

In both Fiji and Samoa, farmers noted that the main product they sell is meat, while manure is primarily used at the household level. In Fiji, farmers mentioned that they don't usually encounter problems in finding customers, as most of them have established long-term relationships with regular buyers. The challenge arises for new farmers entering the sector, especially after the Covid pandemic. In Samoa, some of the farmers interviewed expressed concerns about the quality of the meat, which is perceived as being less good or tasty than imported meat. This perception could potentially impact their business if not addressed properly. To maximize the potential of sheep farming, it was also recognized that there is a need to build and strengthen the market and sales aspect of the business, shifting the mindset from a *hobby* activity to a more business-oriented approach.

7.2.2 Gendered division of labour

The FGDs revealed that women farmers play a vital role in the daily management of small ruminants (SR) in both Fiji and Samoa. SR farming is deeply integrated into family activities in Fiji, while it is relatively new in Samoa (Figure 4 and Figure 5). This difference is reflected in gender roles, which are more rigid in Fiji than in Samoa. In Fiji, strong and rigid gender norms confine women to the domestic sphere, as they are primarily responsible for household and domestic chores. The proximity of goats and sheep to the farmers' homes, especially in subsistence farming, makes women the primary and caring guardians of SR. SR are also described as easy to handle and care for compared to larger livestock. In general, their care appears to be compatible with other traditional tasks carried out by women during the day.

In various activities related to SR management, women and men undertake complementary roles, sometimes interchangeable (e.g. drenching or opening/closing gates). Additionally, wives and husbands often work together, involving children in certain tasks. For instance, drenching involves active participation from everyone in the household. However, in some cases, socially enforced attitudes and behaviours strongly influence the roles of women and men. Certain tasks are reserved or perceived as more suitable for women, while others are reserved for men. Women primarily act as caregivers to pregnant animals or their offspring, expressing a deep emotional connection with the animals, saying, '*As women, we know the pain*.'

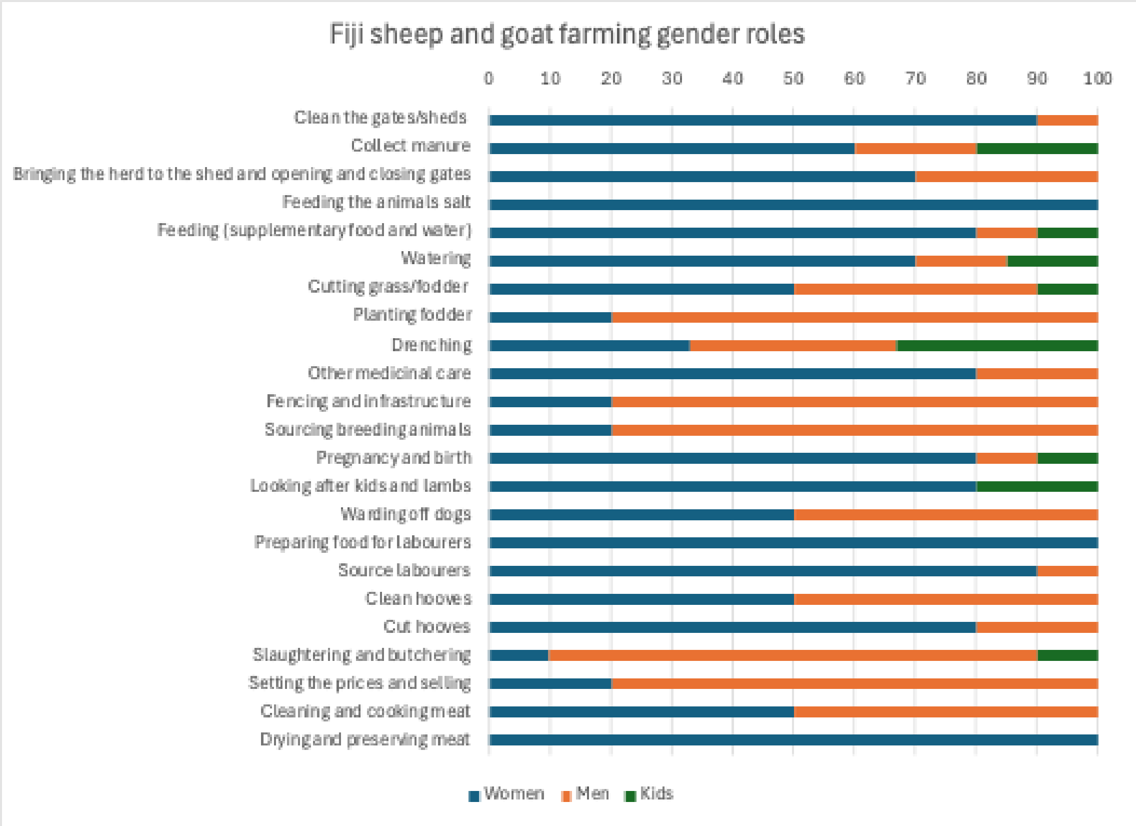

Figure 4: Distribution of work activities in Fijian small ruminant farms based on gender and age group.

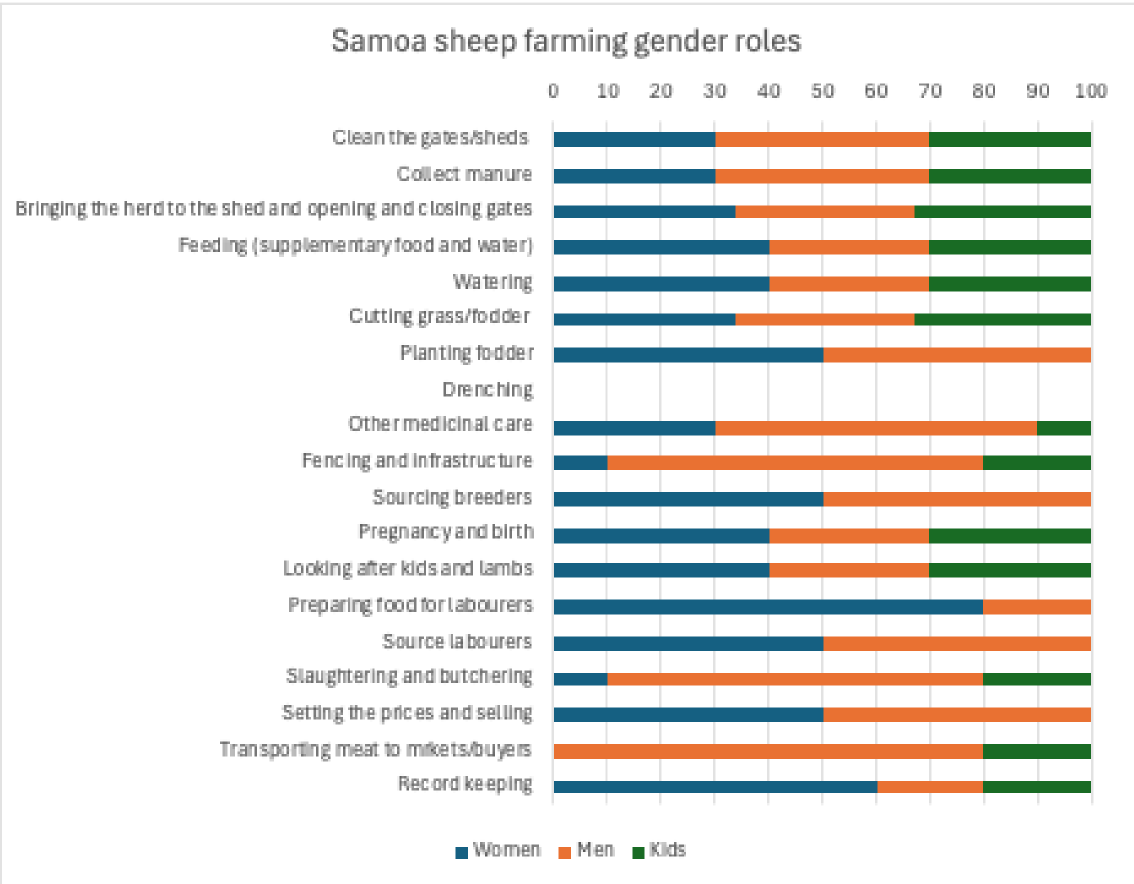

Figure 5: Distribution of work activities in Samoan small ruminant farms based on gender and age group.

In marketing and selling, men predominantly control the trade of goats and sheep, except in cases in the Western Division of Fiji where women determined prices due to the absence of a male household member. Slaughtering animals was typically performed by men in the Indo-Fijian community. In the iTaukei community, women sometimes undertook this task. Gender stereotypes and relations often determined who performed slaughtering in the Indo-Fijian community, attributing the role to men due to the perception that women give life and hence cannot take it.

During validation discussions in Fiji, it became evident that structural changes in agriculture have led to the 'feminisation of agriculture.' As male heads of households increasingly engage in second employment outside the family farm, women are assuming a larger share of agricultural labour or management roles. For example, women are now playing a more significant role in marketing and negotiation with customers, facilitated by access to phones which ensures smoother communication among family members.

In Samoa, similar gendered labour patterns emerged from the discussions. Women farmers are heavily involved in day-to-day farm operations, similar to managing their households. They play a key role in ensuring quality labour, sourcing feed, providing water, and addressing dog-related issues. Women often manage finances in most families and take a strong interest in selling and the financial aspects of sheep farming.

Despite women's substantial contributions to the sector, persistent gender norms prevail, overshadowing their work and limiting opportunities within the sector. The prevailing perception in both Fiji and Samoa is that men are primarily seen as the farmers and owners of livestock and land. In Fiji, women farmers expressed that they were generally not recognized as farmers or owners of small ruminants by the community, despite considering themselves as farmers, albeit not as owners or co-owners, except for a few women who identified as sole owners of the SR. Similarly, in Samoa, particularly concerning customary lands where chieftain (matai) titles are mostly held by men, men are more likely to be acknowledged as the sole farmers.

7.2.3 Access to knowledge sharing and extension

The majority of farmers involved in the FGDs never attended a formal training. It was noted that if the opportunities arise, men will attend by default - as the farmer of the family, head of family, and hence responsible for it. In Fiji, most of the women farmers shared a strong interest in animal care and health; specifically, on how to assist pregnant does/ewes; their babies; or sick animals; how to properly give medicine. In Samoa, most of the women farmers shared interest in the *basic of farm management, animal management and husbandry* including *business related training* (budgeting, record keeping).

In general, farmers shared that they would prefer to receive knowledge through practical training where possible. The use of social media is quite common among farmers, and it was indicated as a good way to obtain and share information. Video demonstrations and simple infographics were suggested. Peer-to-peer knowledge sharing via farm visits or other networking events was also among the preferred methods to enhance knowledge among participants.

7.2.4 Challenges

Farmers raised various structural problems of the sector, such as inadequate infrastructure, inconsistent provision of medicine, wild dog attacks, and natural disasters, as key factors hindering their participation in and benefits from the sector. While these structural problems negatively affect the overall livelihood of the families and growth of the sector, they further reinforce existing gender and social inequalities (summarized in the

Gender at Work framework below) limiting women's and other underserved groups' involvement.

Gender stereotypes, rigid gender roles, social norms and patrilineal customary land tenure systems are some of the underlining causes leading to the challenges women face preventing them from fully develop their potential. Understanding and addressing these challenges can guide the development of interventions and strategies to promote gender equality and empower women across the project and sector.

7.2.5 Project engagement level

In designing and implementing the FGDs at community level, systematic efforts by the project team have been taken to reach out the targeted FGDs participants, specifically women farmers. By adopting a culturally and gender sensitive approach, the project successfully reached out to women farmers through the FGDs discussions. Inclusive practices considering women's specific needs and cultural factors were taking into consideration in the planning of the FGDs; e.g. *child care, school holidays, diet requirements, religious functions*. The collection of disaggregated data by gender has been systematically introduced in project activities as good and best practice.

As a result, the project has successfully established new databases in Fiji and Samoa, which now contain information and contact details of women farmers. This stands in contrast to the initial database, which only included details of male farmers, thereby perpetuating the perception of SR sector as a male-dominated space and obscuring the significant contributions made by women. The new databases will be used to target participants for future project capacity building opportunities and events.

The FGDs, and the designed research tools and approach, were successful in getting qualitative data and information capturing women farmers' experiences and gender issues within the sector. It was a good opportunity to identify women role model who could play a strategic role in future project activities. They were also a vital opportunity for knowledge sharing and networking among farmers. Finally, the project made considerable progress in delivering messages through social media aiming at emphasising women's contribution to SR also through the celebration of specific International Days e.g International Women's Day, International day of Rural Women (Figure 6).

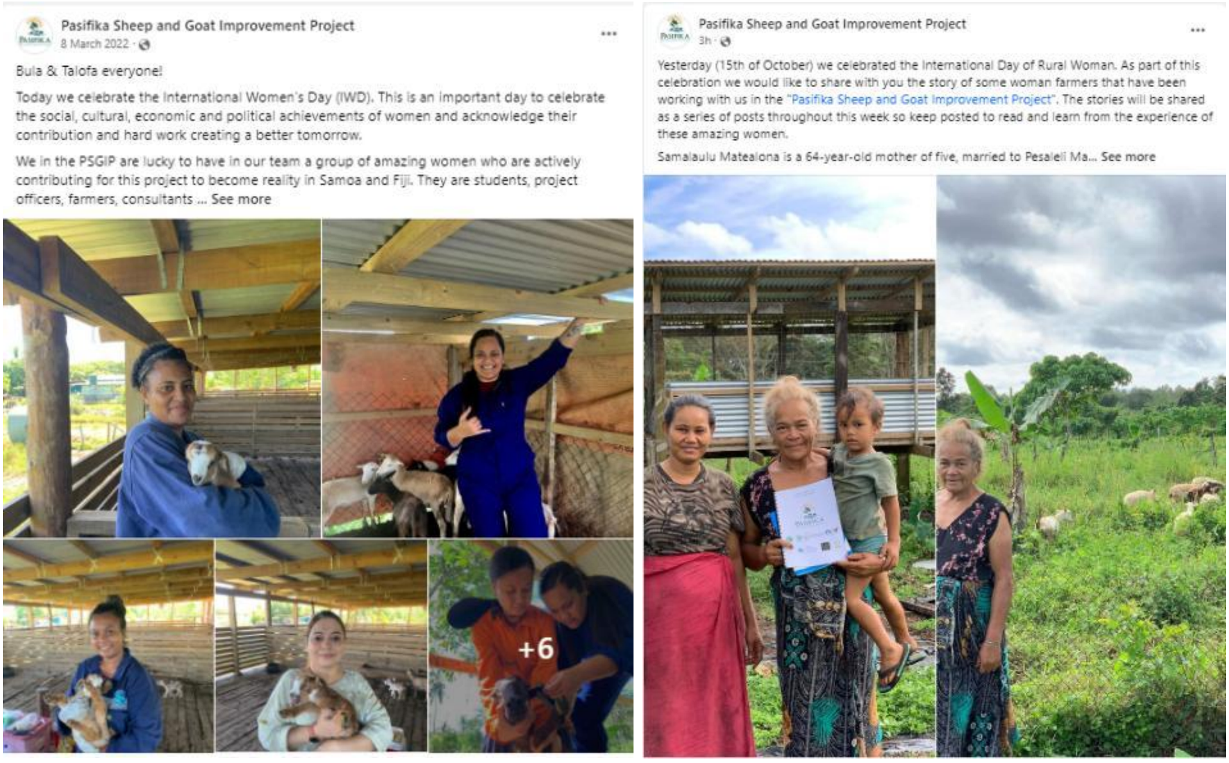

Figure 6: Facebook posts celebrating the International Women's Day on the 8th of March and International day of Rural Women on 15th of October.

7.2.6 GESI recommendations

Based on the findings and insights presented, some recommendations were designed in order to contribute to create a conducive environment that facilitates and supports women's engagement in the sector. These recommendations were grouped in three main areas, as summarized in Figure 7.

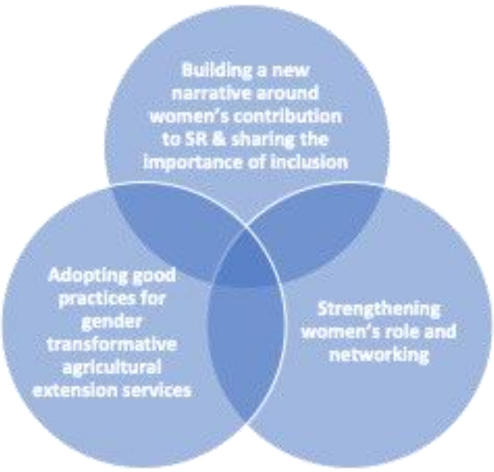

Figure 7: Representation of PSGIP GESI recommendations.

There is the need to build a new and visible narrative around women's contribution to the SR sector as a prerequisite for fair and equal opportunities. Concrete actions and recommendations are needed to acknowledge and transform perceptions around women's involvement in the SR sector:

- **Build a new narrative** recognizing women's significant contributions to agriculture, strategically positioning women's role models throughout project activities.
- **Make women's work visible** through sex-disaggregated data (or by gender if possible) and relevant knowledge products.
- **Tailor agricultural extension services** by catering to women's needs both logistically and content-wise and specifically target women's involvement and participation.
- **Create Women's Groups and Networks** to strengthen women's roles through strategic partnerships, awareness initiatives, networking, and targeted technical training, with the potential to enhance women's decision-making power at the household level and within the broader community.
- **Contribute to the implementation of regional and national frameworks and policies** for gender equality and the advancement of women and their families.

7.3 Baseline survey of small ruminant systems in Fiji and Samoa.

The results obtained in the baseline survey are presented in Table 4, Table 5 and Table 6. Most of the differences can be grouped by countries however some differences within country can also be observed and will be discussed in this section.

The results shows that the great majority (over 85%) of the "identified" farmers are male despite that it's also known that other family members (e.g. wife, elderly parents and children) also have significant contributions in these households (Table 4). Most of these farmers were married and were of Indo-Fijian (91 – 94%) and Samoan (100%) ethnicity in Fiji and Samoa respectively. Farmers in Upolu were almost 10 years older than farmers in Savai'i (56.1 vs 45.8) while no major differences were observed across the other locations. Fijian farmers have significantly more years of SR farming experience when compared to Samoan farmers, which could be a factor of the relatively recent (2004) introduction of SR in Samoa compared to Fiji. Samoan farming families were larger than those in Fiji. In addition, the Samoan farmers tended to have a higher weekly income with the majority of farmers having an off-farm source of income compared to Fiji (75.5 vs 38.2 %). A bit less than half of the farms used some type of external labour supply and the majority of it consisted of paid labour in all locations. However, in Fiji this was predominantly composed of temporary labour while in Samoa the labourers were on a long-term contract. There was no difference in terms of payment to employees by location, however these values are given in the local currency for each location and varied from 3.8 to 4.3 FJD$/hour in Fiji and 4.4 to 5.1 WST$/hour in Samoa. We also observed significant differences in terms of farm size; farms in the Northern Division were significantly bigger than the Western division of Fiji (15.8 vs 8.5 ha) and these were also significantly bigger than Samoan farms (2.6 and 1.7 ha in Upulo and Savai'i, respectively). The type of land ownership also varied across locations, in the Western division of Fiji the most common is TLTB (iTaukei Land Trust Board) lease while freehold land is more common in the Northern Division. In Samoa, the majority of the farmers reported to own freehold land (Table 4), however in communication with local researchers we were informed that the majority of these areas are in fact customary land and farmers report as freehold given that this would portray them as a higher social economic-status.

Table 4: Descriptive parameters of household information of small ruminant farmers in Fiji and Samoa.

Parameters	Fiji		Samoa		ANOVA *P*-Value	χ^2 *P*-Value
	West (n=60)	**North** (n=71)	**Upolu** (n=27)	**Savai'i** (n=26)		
Gender (%)						
Male	93.3	87.3	88.9	84.6	-	0.599

Female	6.6	12.7	11.1	15.3		
Age (yrs)	**47.4a**	**51.0ab**	**56.1b**	**45.8a**	**0.006**	-
Education level (%)	αδ	α	β	βδ		
No formal education	1.7	0	0	0		
Primary school	25.0	43.7	11.1	7.7	-	**<0.001**
High school	63.3	46.5	48.1	69.2		
Undergraduate	8.3	9.9	40.7	23.1		
Post-graduate	0	0	0	0		
Farming experience (yrs)	15.4**a**	17.8**a**	9.6**b**	5.3**b**	**<0.001**	-
Marital status (%)						
Single	10.0	4.2	0	11.5		
Married	85.0	91.5	92.6	88.5	-	0.320
Divorced	3.3	2.8	0	0		
Widowed	1.7	1.4	7.4	0		
Ethnicity (%)	α	α	β	β		
Samoan	0	0	100	100		
iTaukei	8.3	4.2	0	0	-	**<0.001**
Indo-Fijian	91.7	94.4	0	0		
European	0	1.4	0	0		
Family members (n)	4.5**a**	4.0**a**	6.2**b**	5.7**b**	**<0.001**	-
Children (0 – 18 yrs)	1.0**a**	0.7**a**	2.8**b**	2.1**b**	**<0.001**	-
Adults (18 – 60 yrs)	3.1	2.9	3.4	3.6	0.379	-
Elderly (> 60 yrs)	0.5	0.3	0.6	0.5	0.771	-
Total household weekly income (%)	α	α	β	β		
0 to 250 (FJ$/WST$)	68.3	62.0	29.6	38.4		
250 to 500 (FJ$/WST$)	18.3	31.0	18.5	23.1		
500 to 750 (FJ$/WST$)	3.3	1.4	11.1	19.2	-	**0.005**
750 to 1,000 (FJ$/WST$)	0	1.4	25.9	15.3		
1k to 2k (FJ$/WST$)	6.7	1.4	14.8	3.8		
2k to 3k(FJ$/WST$)	0	1.4	0	0		
3k or greater (FJ$/WST$)	3.3	1.4	0	0		
Off-farm income (%)	β	α	αβ	β		
Yes	58.3	21.1	70.3	80.7	-	**0.004**
No	41.6	78.8	29.6	19.2		
Family members working on-farm (n)	1.5**a**	2.2**b**	2.3**b**	2.2**b**	**<0.001**	-
Family members have off-farm income (%)	β	α	β	β		
Yes	38.3	12.6	68.0	53.8	-	**0.005**
No	61.6	87.3	32.0	46.2		
Family members working off-farm (n)	1.4	1.1	2.0	1.4	**0.103**	-
External farm labour (%)						
Yes	36.7	31.0	51.8	53.8	-	0.114
No	63.3	69.0	48.1	46.1		
Monetary payment to farm labour (%)						
Yes	81.8	86.4	100	100	-	0.121
No	18.2	13.6	0	0		
Type of employment (%)	α	α	β	β		
Temporary employment	83.3	78.9	21.4	0	-	**<0.001**
Permanent employment	16.7	21.1	78.5	100		
Number of employees (n)	3.0	2.4	2.7	2.7	0.821	-
Payment to employees (FJ$ or WST$ / hour)	3.8	4.3	5.1	4.4	0.118	-
Have measured property area (%)						
Yes	86.7	84.5	81.5	88.4	-	0.896
No	13.3	15.5	18.5	11.5		
Total farm area (ha)	8.5**b**	15.8**a**	2.6**c**	1.7**c**	**<0.001**	-
Land ownership type (%)	α	δ	β	β		
Freehold	28.3	35.3	77.7	92.3	-	**<0.001**
Customary	0	0	14.8	7.7		
Leasehold	6.7	4.2	7.4	0		

Mataqali	8.3	31.0	0	0		
TLTB	38.3	26.8	0	0		
Other	18.3	2.8	0	0		

In terms of flock and herd size, sheep only farms in the Northern Division of Fiji had larger flocks than farms in the Western Division (56 vs 34 head/farm) as well as Samoan farms (Table 5). There were no regional differences in flock size within Samoa. Interestingly, there was no difference between locations when analysing the total number of animals in goats only farms as well as farms with sheep and goats. A larger proportion of farmers in the Northern Division of Fiji reported to have purchased SR over the previous year when compared to farmers of all other locations (approximately 70 vs 30%). Of famers which purchased SR stock, these purchases were mostly sourced from other farmers in Fiji and from Ministry of Agriculture in Samoa.

The diversity of these enterprises can be assessed by the proportion of farms that raise other livestock's and grow crops in their properties. In this sense, Samoan farmers tended to be involved with beef cattle production while Fijian farmers presented a greater diversity of livestock commodities divided into beef, dairy and poultry. The variety of crops produced in Samoa was very similar between islands but different to the plants cultivated in Fiji. Farms in the Northern Division of Fiji reported a greater variety of crops when compared to farms in the Western Division. The size of the pasture area in each location showed a similar trend to the differences observed in relation to total farm size, with farms in Northern Fiji having the largest areas followed by Western Fiji and then by Samoan farms. Setaria is the most common improved pasture in Samoa while, Koronivia grass and Juncao are more common in Fijian farms.

Table 5: Descriptive parameters of farm structure of small ruminant farmers in Fiji and Samoa.

Parameters	**Fiji**		**Samoa**		**ANOVA *P*-Value**	**χ^2 *P*-Value**
	West (n=60)	**North** (n=71)	**Upolu** (n=27)	**Savai'i** (n=26)		
Sheep flock size (n)						
Rams	3.9**b**	6.3**c**	1.7**a**	2.1**a**	**<0.001**	-
Ewes	27.2**a**	27.5**a**	8.1**b**	8.5**b**	**<0.001**	-
Growing male	8.3**b**	11.4**a**	2.5**c**	1.6**c**	**<0.001**	-
Growing female	9.2**a**	13.3**c**	3.1**b**	5.8**ab**	**<0.001**	-
Goat herd size (n)						
Bucks	5.5	6.9	-	-	0.586	-
Does	42.3	36.1	-	-	0.473	-
Growing male	13.8	16.0	-	-	0.401	-
Growing female	16.1	17.2	-	-	0.499	-
Total number of SR (n)						
Sheep only farms	34.9**b**	56.6**a**	15.4**c**	18.1**c**	**<0.001**	-
Goats only farms	81.3	71.2	-	-	0.602	-
Sheep and goat's farms	142	144	-	-	0.915	-
Purchased SR previous year (%)	β	α	β	β	-	**<0.001**
Yes	31.7	71.8	25.9	34.6		
No	68.3	28.2	74.0	65.3		
Source of purchased animals (%)	α	α	β	αβ	-	**<0.001**
Ministry of Agriculture	10.5	9.8	71.4	44.4		
Another farmer	89.5	90.2	28.5	55.5		
Livestock raised by farmers (%)						
Beef cattle	26.6αδ	16.9α	55.5βδ	61.β	-	**0.008**
Dairy cattle	30.0α	49.3α	0β	0β	-	**<0.001**
Pork	1.7α	2.8α	11.1β	4.1β	-	**0.021**
Poultry	35.0α	83.1δ	7.4β	11.5βα	-	**<0.001**
Horses	13.3	7.0	0	0	-	0.060

Bees	1.7	4.2	0	3.8	-	0.693
Beef cattle herd size (n)	32.7	15.0	21.6	13.7	0.210	-
Dairy cattle herd size (n)	18.1	16.2	-	-	0.736	
Co-grazing cattle & SR (%)	31.0	60.9	46.6	37.5	-	0.070
Cropping on-farm (%)	α	β	αβ	αβ		
Yes	46.7	83.1	63.0	61.5	-	**0.001**
No	53.3	16.9	37.0	38.5		
Have measured crop area (%)						
Yes	67.9	50.8	70.5	43.7	-	0.200
No	32.1	49.2	29.4	56.2		
Crop area (ha)	2.4**a**	2.0**ab**	1.0**c**	1.1**bc**	**0.024**	-
Crops cultivated by farmers (%)						
Dalo	1.7α	9.9α	48.1β	42.3β	-	**<0.001**
Coconut	6.7β	15.5αβ	37.0αδ	50.0δ	-	**<0.001**
Fruit trees	8.3β	21.1αβ	37.0α	42.3α	-	**0.003**
Forestry	0α	0α	18.5β	23.0β	-	**<0.001**
Cacao	0α	0α	40.7β	23.1β	-	**<0.001**
Cassava	10.0β	39.4α	18.5αβ	42.3α	-	**<0.001**
Corn	13.3αβ	25.4α	0β	0β	-	**0.001**
Rice	5.0β	45.1α	0β	0β	-	**<0.001**
Beans	8.3β	56.3α	7.4β	0β	-	**<0.001**
Sugarcane	38.3α	25.4α	0β	0β	-	**<0.001**
Have measured pasture area (%)						
Yes	41.7	35.2	51.8	38.4	-	0.507
No	58.3	64.8	48.1	61.5		
Pasture area (ha)	2.6**b**	6.1**a**	1.1**c**	0.8**c**	<0.001	-
Have improved pastures (%)	α	α	β	αβ		
Yes	16.7	16.9	44.4	38.4	-	0.005
No	83.3	83.1	55.5	61.5		
Improved pastures utilised (%)						
Setaria	0α	0α	44.4β	34.6β	-	**<0.001**
Guatemala	0	4.2	3.7	7.7	-	0.277
Juncao	15.0α	8.5αβ	0β	0β	-	**0.043**
Koronivia	3.3αβ	15.5α	0β	0β	-	**0.003**
Baitiki	0β	1.4αβ	0β	11.5α	-	**0.008**
Mulato	1.7	2.8	0	0	-	0.778
Leucaena	1.7	0	0	0	-	0.611
Elephant grass	0	1.4	0	0	-	0.989

Overall, the great majority of farmers don't practice any type of information recording, and this was similar across all locations (Table 6). Among farmers which did practice recording the most common information was the number of stocks in the farm and number of animals sold. The estimated mortality rate of adults varied significantly across locations with the highest being recorded in farms in Upolu (25%) and Northern Division of Fiji (19%). There was no difference between location observed for growers' mortality and the range estimated was from approximately 17 to 28%. A surprisingly high proportion (66 to 95%) of farmers reported to receive some type of agriculture advice in all locations and the most common source was from staff members of the Ministry of Agriculture of each country. Most farmers reported to own an animal house, where SR were locked up at night, but it was slightly less common in Western farms compared to the other locations. Mineral supplementation was reported to be practiced by approximately half of the farmers interviewed while fodder and concentrate supplementation were more common on the main islands of each country (i.e. Upolu and Western Division). Castration was rarely practiced in Fiji while it was adopted by around half of the farms in Samoa. The grazing time (i.e. time span between when animals are released in the morning and locked up in the animal house at night), was significantly longer for Samoan farms (9.9 and 11h) compared to Fijian Farms (7.6 and 7.6h).

Drenching animals with anthelmintics was common to all farms and this practice was usually performed by the farmers and their family members in Fiji, while in Samoa it was conducted by the Ministry of Agriculture staff. In Fiji, anthelminthics are supplied mostly through the Ministry of Agriculture. In Samoa, although agricultural stores stock anthelminthics, in practice, all farmers involved in the project sourced the anthelminthics and labour for drenching from the Ministry of Agriculture and Fisheries. The majority of Samoan farmers therefore reported not to know the drugs that have been utilised more recently in their farms as well as over the last 5 years. Fijian farmers have predominantly used Levamisole but over the last 5 years they also reported the usage of Albendazole. The monetary expenditure on drenches was similar across Fiji and Upolu with the difference that farmers in Savai'i reported a substantially lower expenditure compared to the other locations. Farmers in Fiji reported to drench their animals on average 8.6 times a year (i.e. every 42 days) while in Samoa this number varied from 2 (i.e. every 6 months) to 4 times (i.e. every 3 months) per year. More than half of Fijian farmers reported to have suspicion of drench resistance problems in their farms while the same was not common in Samoa. In Fiji, dog predation, adult mortality and thefts were reported as the main limitations for greater productivities while in Samoa dog predation, limited grazing area and lack of information were commonly reported. Farmers were also asked where they would like to invest capital if they could improve their farms. The two most common answers across all locations were to purchase more stock and farm equipment's.

Table 6: Comparison between management practices between small ruminant farms in Fiji and Samoa.

Parameters	Fiji		Samoa		ANOVA *P*-Value	χ^2 *P*-Value
	West (n=60)	North (n=71)	Upolu (n=27)	Savai'i (n=26)		
Record herd information (%)						
Yes	21.7	36.6	22.2	11.5	-	0.052
No	78.3	63.4	77.7	88.4		
Type of information recorded (%)						
Number of stock	20.0	18.3	11.1	3.8	-	0.241
Sales	1.7	9.9	11.1	7.6	-	0.237
Price of sales	0	4.2	0	0	-	0.207
Adult mortality rate (%)	11.6**c**	19.4**ab**	25.4**a**	12.7**bc**	0.001	-
Growers' mortality rate (%)	17.6	22.9	28.9	22.5	0.187	-
Receive agricultural advice (%)	66.7β	95.8α	85.2αβ	80.7αβ	-	**<0.001**
Own an animal scale (%)	36.7β	22.5αβ	18.5αβ	7.6α	-	**0.020**
Own an animal house (%)	48.3β	73.2αβ	81.4αβ	96.1α	-	**<0.001**
Practice mineral supp. (%)	36.7	57.7	55.5	46.1	-	0.095
Practice concentrate supp. (%)	33.3β	4.2α	29.6β	3.8α	-	**<0.001**
Practice fodder supp. (%)	20.0β	5.6αβ	14.8αβ	3.8α	-	**0.035**
Practice castration (%)	3.3α	1.4α	48.1β	57.6β	-	**<0.001**
Practice weaning (%)	16.7	5.6	11.1	7.6	-	0.206
Practice drenching (%)	95.0α	97.2α	77.8β	65.4β	-	**<0.001**
Grazing time (h)	7.6**a**	7.6**a**	9.9**b**	11.0**b**	-	**<0.001**
Responsible for drenching (%)						
Survey respondent	81.7α	87.3α	14.8β	11.5β	-	**<0.001**
Family member	11.7	11.3	3.7	0	-	**0.223**
Ministry of Ag staff	0α	0α	59.2β	53.8β	-	**<0.001**
Farm worker	3.3	0	0	0	-	0.1884
Last drench used (%)	α	α	β	β		
Albendazole	1.8	1.4	9.1	0		
Levamisole	98.2	98.6	9.1	0	-	**<0.001**
Not known	0	0	81.8	95.6		
Other	0	0	0	4.3		
Drenches used over the last 5 years						

Albendazole	13.3β	40.8α	7.4β	0β	-	**<0.001**
Levamisole	95.0α	97.2α	7.4β	0β	-	**<0.001**
Not known	0α	0α	66.6β	84.6β	-	**<0.001**
Other	5.0	9.9	0	3.8	-	0.266
Expenditure drench per head (FJ$ or WST$ / head)	2.5**a**	2.0**a**	1.8**a**	0.1**b**	**<0.001**	-
Weight measurement before drenching	66.7α	7.2α	63.6β	47.8αβ	-	**<0.001**
Drenching grouping	α	α	β	β		
Individual animals	31.6	31.9	68.2	78.2	-	**<0.001**
All animals	68.4	68.1	31.8	21.7		
Number of drenching events over previous year (n)	8.7**a**	8.6**a**	2.0**b**	4.4**b**	**<0.001**	-
Knowledge of drench resistance	α	α	β	β		
Yes	73.3	25.4	14.8	3.8	-	**<0.001**
No	26.7	74.6	85.1	96.1		
Drench suspicion	α	α	β	β		
Yes	73.7	50.7	0	13.6	-	**<0.001**
No	26.3	49.3	100	86.3		
Main productive limitation (%)	δ	α	βδ	β		
Dog attack	38.3	43.7	40.7	26.9		
Adult mortality	8.3	19.7	3.7	0		
Young mortality	6.7	9.9	3.7	7.7		
Diseases	5.0	2.8	0	0		
Lack of information	1.7	4.2	18.5	42.3	-	**<0.001**
Low growth rate	1.7	4.2	0	3.8		
Low reproductive rate	5.0	2.8	7.4	0		
Theft	10.0	11.3	3.7	0		
Not enough grazing area	23.3	1.4	22.2	19.2		
Farm investments (%)	β	α	α	αβ		
Animal feed	8.3	0	11.1	3.8		
Farm infrastructure	1.7	8.5	0	0		
Pasture planting	26.7	1.4	0	11.5	-	**<0.001**
Farm equipment	28.4	31.0	40.7	34.6		
Stock	21.7	54.9	48.1	46.2		
Land	13.3	4.2	0	3.8		

The analysis of worm burden (ie faecal egg count, FEC) data was conducted separately for each for each country given the different methodology utilised to group the samples in each location. In Fiji a total of 3,450 animals were sampled for this study. In Fiji, the factors investigated were location (i.e. West or North), season when it was collected (i.e. wet or dry season), animal species (i.e goat or sheep), animal sex (i.e. male or female) and animal category (i.e. lactating females, dry adults or growing animals). Worm burden was not affected by location, sex or species. Lactating females (701 epg) and young animals (934 epg) presented significant higher ($P < 0.001$) than dry adults (453 epg) and samples collected during the Wet Season also presented significant higher (411 *vs* 1,203 epg; $P = 0.01$) counts when compared to the Dry Season (Fig 4). In Samoa, the analysis of the FEC data showed no significant difference between locations (i.e. Upolu vs Savai'I; 128 vs 61 epg; $P = 0.11$) or animal category (i.e. adults vs young animals; 106 vs 70 epg; $P = 0.38$). In Samoa, all samples were collected between November and December 2021 during the Wet Season. The data from Samoa shows a surprisingly low level of FEC which was unexpected.

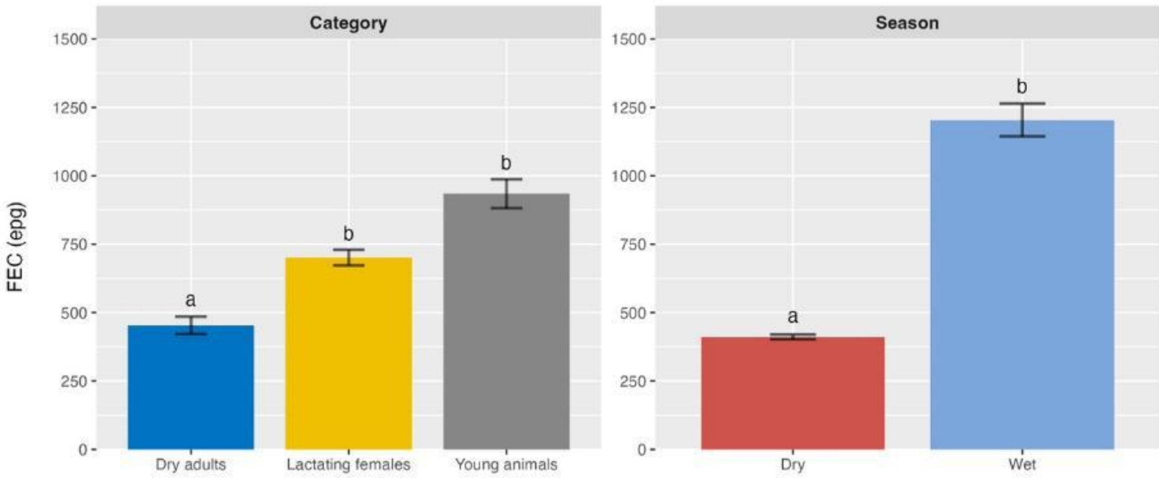

Figure 8: The effect of category and season on faecal egg count (FEC) results of sheep and goats (n = 3,450) across Fijian farms. Data presented are arithmetic means and error bars represents the standard error of the mean. Different letters within groups (i.e. category or season) denote *P* < 0.05.

Taken all together the results seem to suggest that Samoan farmers are of a higher socio-economic status than Fijian farmers. They also seem to be less dependent on farm income given the higher proportion of farmers and family members having an off-farm income as well as the fact that most of these farms are run by a permanent farm worker who is usually responsible for the farm activities. On the other hand, Fijian farms are more dependent on farm income and resources, especially in the Northern Division where a smaller proportion of farmers and family members have an outside job. In addition, in the Northern Division farms have a greater variety of crops which are usually for subsistence purposes. These observations can be explained by the difference in terms of infrastructure and resources between the Western and Northern Division. In addition, these differences could be the reason to explain the trends observed in relation to the level of adoption of fodder and concentrate supplementation. Farmers from all locations and both countries seemed to have similar opinions in relation to the main problems faced by the industry with dog predation being routinely mentioned by farmers. Is interesting to notice that lack of grazing area was identified as a problem by a large proportion of farmers, yet when asked where they would like to invest money to improve their farms the most popular answer was to purchase more stock, despite the very low adoption of improved pastures. This answer seems to demonstrate a lack of holistic awareness of farmers in relation to factors restricting their production systems. Farmers in Samoa have a lower level of awareness in relation to the anthelmintic drugs utilised in their properties. This can be explained based anthelmintics are commercialised and administered in Samoa directly by Ministry of Agriculture staff members. However, this doesn't seems to affect the efficiency of control given the relatively low FECs across all farms. The FEC results obtained in Fiji during the baseline survey are in agreement with other studies conducted in this project (see anthelmintic resistance trial) as well as background information in the literature.

7.4 On-farm monitoring program of sheep and goats in Fiji and Samoa.

The main goal of the on-farm monitoring program was to generate more detailed information about the production parameters, productivity levels and limitations on small ruminant farms in Fiji and Samoa. In this section we will be presenting these results and try to establish some comparisons in relation to small ruminant species (i.e. sheep or goats) and locations. The results have been separated into subsections in order to facilitate comprehension. We have also aimed to generate some production benchmarks so that can be utilised in the future to gauge productivity in these systems. The benchmarks were generated by calculating the productive parameters for each farm and presenting the distribution of this data based on the 25, 50 and 75th percentiles.

7.4.1 Growth performance from birth to 180 days.

The growth data of lambs and kids from birth (day 0) until 180 days of age (approximately usual weaning) was modelled using data collected from each farm and is presented in Figure 9. There are some clear distinctions in the growth path that can be observed. Firstly, there is a large difference in terms of growth rate and liveweight at 180 days when comparing sheep and goats. On average, goats reached 180 d of age at approximately 14.7 kg and sheep at 21.4 kg, which gives an average overall liveweight gain (LWG) of around 67 and 103 g/head.day, for kids and lambs respectively. There are also some variations caused by type of birth (i.e. single, twins or triplets), sex (i.e. male or female) but these are minor, and we will not be focusing on this point here. Secondly, a more distinct spread in terms of performance can be observed within sheep farms. This suggest that there was a larger variation in terms of growth performance among the sheep farms than goat farms, which potentially suggests differences in the scope for improvement.

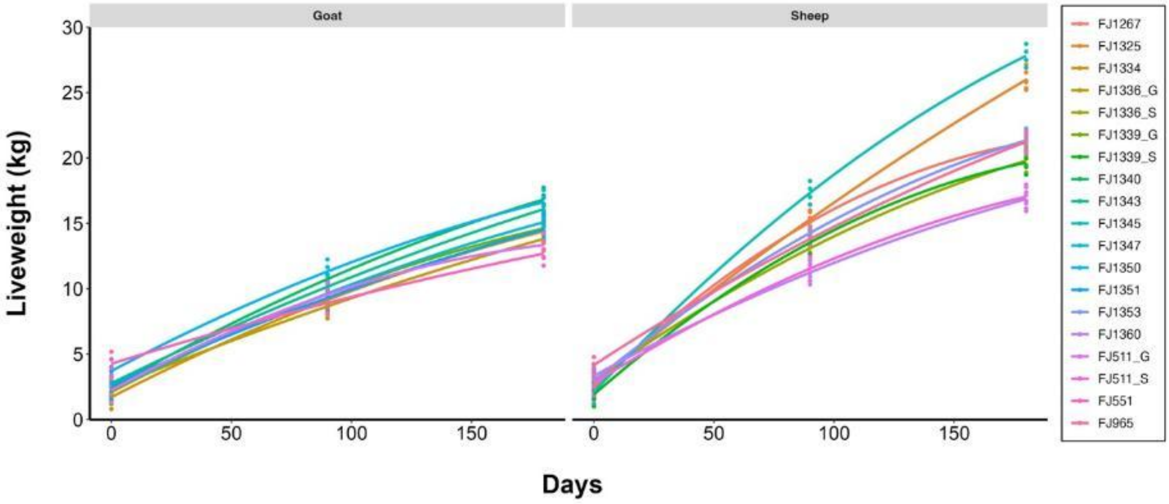

Figure 9: Liveweight of kids and lambs from birth until 180d of age on Fijian farms.

In Table 7 we present the distribution of liveweight at birth, 90 and 180 days based on species and age. At 180d, goats from farms on the bottom 25th percentile weighed approximately 13.7 kg compared to 15.8 kg for goats on farms in the top 75th percentile. In practical terms, this means that the difference between the best performing, and worst performing goat farms is approximately 2 kg at day 180. This suggests that improvement in goat growth rates may require changes that few farms are currently implementing. When the same comparison is made across sheep farms in Fiji a difference of 6.3 kg is observed. This difference translates into a LWG of 65 to 69 g/head.day and 93 to 121 g/head.day for the worst and best performing goats and sheep in Fijian farms respectively, and suggests that there is significant potential for improvement by the bottom 25th percentile of farms, if the 75th percentile is considered the benchmark, but that there are changes already in practice by at least a quarter of sheep farmers that could offer potential for underperforming farms to improve their productivity.

Table 7: Liveweight of growing kids and lambs at birth (day 1), 90 and 180 days old. The averages include all types of birth (i.e. single, twins and triplets) and sex (i.e. male and female).

Country	Species	Age (days)	Liveweight (kg)			n of farms
			25th percentile	Median	75th percentile	
Fiji	Goat	1	1.89	2.57	3.32	10
Fiji	Goat	90	8.82	9.82	10.4	10

Fiji	Goat	180	13.7	14.7	15.8	10
Fiji	Sheep	1	2.06	2.68	3.33	9
Fiji	Sheep	90	12.6	14.0	15.2	9
Fiji	Sheep	180	18.9	20.7	25.2	9
Samoa	Sheep	1	3.17	3.31	3.67	8
Samoa	Sheep	90	12.1	14.3	15.5	8
Samoa	Sheep	180	19.2	20.7	23	8

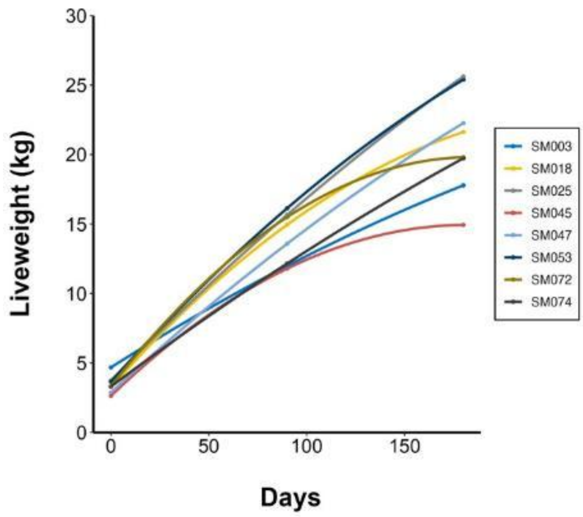

Figure 10: Liveweight of lambs from birth until 180d of age on Samoan farms.

The growth pattern as well as the liveweight of lambs in the top and bottom performing farms in Samoa was very similar to the values observed for sheep farms in Fiji. In both countries the genetic base of the sheep flock is composed mainly of Fiji Fantastic animals despite some recent initiatives of the Ministry of Agriculture and Fisheries of Samoa to develop their own breed (Mamoe Samoa) by crossing Fiji Fantastic with Black-headed Dorper.

7.4.2 Reproductive performance

The percentage of mature females giving birth within a year (i.e. conception rate) was measured in each farm. The results were investigated using location and species as explanatory variables and are presented in Figure 11. The model predicts the average conception rate to be higher (74.9 *vs* 66.1%; P =0.007) in the Northern division compared to the Western, this effect is caused by an unexpected higher birth rate for goats in the Northern division. Goats in the Northern division presented 2.4 times greater odds ($P < 0.05$) of giving birth within a year compared to goats in the Western Division. The lambing / kidding rate results followed a similar result to the conception rate (Figure 11). This suggests that this parameter was more influenced by the proportion of “empty” females in each farm than any possible differences in birth type (i.e. singles, twins or triplets). The overall lambing/kidding rate was close to 90% which means that for a group of 100 ewes or does there would be approximately 90 lambs or kids born within that year. It’s important to notice that these calculations were made on a year base while in some publications the lambing or conception rate might be reported for each joining period.

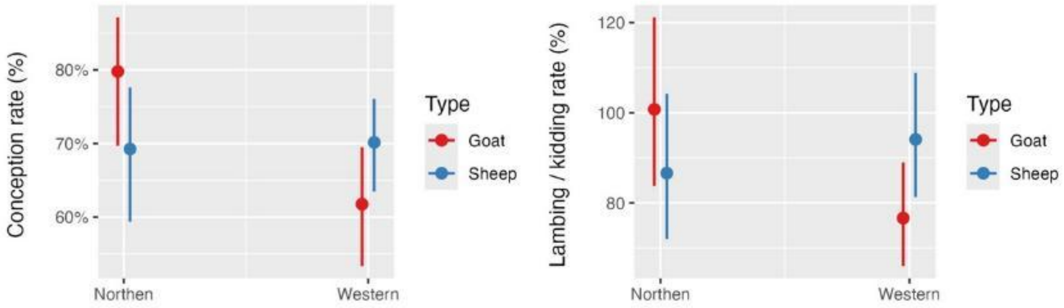

Figure 11: Effect of species and location on conception and lambing / kidding rate of small ruminants in Fiji. Conception rate was investigated using a logistic mixed-model regression which presented a non-significant effect for species (*P* = 0.125), a significant effect for location (*P* = 0.001) and its interaction (*P* = 0.02). Lambing / kidding rate was assessed using a poisson regression model where a tendency for location (*P* = 0.052) effect and species (*P* = 0.066) was observed. The interaction between location and species was significant (*P* = 0.029). Error bars represent the 95% confidence interval.

Table 8 presents the distribution of conception and lambing / kidding rate data and the achievable targets (75th percentile) for each species and region. The conception rate data represents the proportion of adult females in a herd or flock giving birth within a year. The results show a large number of empty adult females (from 17.2 to 40.7%) not giving birth within a year, which represents a large reproductive inefficiency. Ideally, conception rate should be over 95%, especially considering that these are all mature females and had been in contact with adult males (i.e. bucks and rams) throughout the whole year. It's important to remember that these values already exclude reproductive females which were sold, died or went missing during the assessment year. Lambing and kidding rate follows a similar pattern to conception rate, but the former parameter also takes into consideration the litter size.

We have not been able to calculate conception rate for Samoan farms given that there was a significant number of lambs born which were not associated to their respective dams. For these farms we have calculated lambing rate based on the total of lambs born within a year divided by total of reproductive females. For this reason, we have excluded the Samoan farms for the statistical analysis, but we are reporting the distribution of the values observed in each farm in Table 8. The lambing rate observed in Samoa was similar across both islands (i.e. Upolu and Savai'i) and comparable to the values observed for Fijian farms. Litter size was very similar across species and location which supports the suggestion that the differences observed in lambing and kidding rate were caused by conception rate. The median litter size varied from 1.17 to 1.39 newborns per birth event which is on the lower end but still comparable to values reported for other tropical breeds of sheep and goats (Combellas 1980; Galina *et al.* 1996; de Lima *et al.* 2020). The distribution of types of births was similar between locations and species. Single births represented 74% (n = 264), 72% (n = 310) and 76% (n = 138) of all births for goats and sheep in Fiji and sheep in Samoa, respectively. Twins composed 26% (n = 92), 27% (n = 117), and 25% (n = 45) of the births for goats and sheep in Fiji and sheep in Samoa, respectively. Triplets were only recorded on one sheep farm in Fiji and it only represented 1% (n = 4) of all birth events recorded. Despite not being able to calculate the conception rate for Samoan farms, we are able to infer that conception rates would be similar to Fiji in these locations given that lambing rates and litter sizes were comparable and lambing rate is a factor of litter size and conception rate.

Table 8: Distribution of conception rate, lambing / kidding rate and litter size data of small ruminant farms in Fiji and Samoa.

Specie	Location	Conception rate (%)			
		25th percentile	Median	75th percentile	n of farms
Goat	Northern	73.2	82.9	88.6	4
Goat	Western	59.0	59.3	70.8	3
Sheep	Northern	66.1	68.2	71.0	3
Sheep	Western	67.4	73.1	79.5	7
		Lambing / Kidding rate (%)			
Goat	Northern	93.1	106.0	116.0	4
Goat	Western	70.6	76.5	97.1	3
Sheep	Northern	75.1	81.0	81.4	3
Sheep	Western	80.6	100.0	102.0	7
Sheep	Upolu	86.9	100.0	112.0	8
Sheep	Savai'i	77.3	100.0	135.0	7
		Liter size (n)			
Goat	Northern	1.28	1.32	1.41	4
Goat	Western	1.35	1.39	1.40	6
Sheep	Northern	1.20	1.21	1.22	3
Sheep	Western	1.27	1.38	1.44	6
Sheep	Upolu	1.00	1.33	1.67	9
Sheep	Savai'i	1.00	1.17	1.54	10

In both countries reproductive females are maintained in the same group together with bucks and rams without any specific joining season. So, birth distribution throughout the year is only influenced by reproductive status of animals. The distribution of all births recorded during the monitoring period is presented in Figure 12. The results suggests that there is a more defined lambing and kidding season in Fiji than in Samoa. Despite the variation in the data, it seems that births of both sheep and goats are concentrated between June to October in both Divisions. Fiji has a more pronounced and well-defined dry season when compared to Samoa and this could be one of the possible reasons for these differences. As weaning is not a common practice a female giving birth in August would probably utilise most of its body reserves in order to produce milk during the end of the dry season and early wet then recover its body reserves throughout the wet season, reconceiving by wet season end, in order to give birth again on the following dry season.

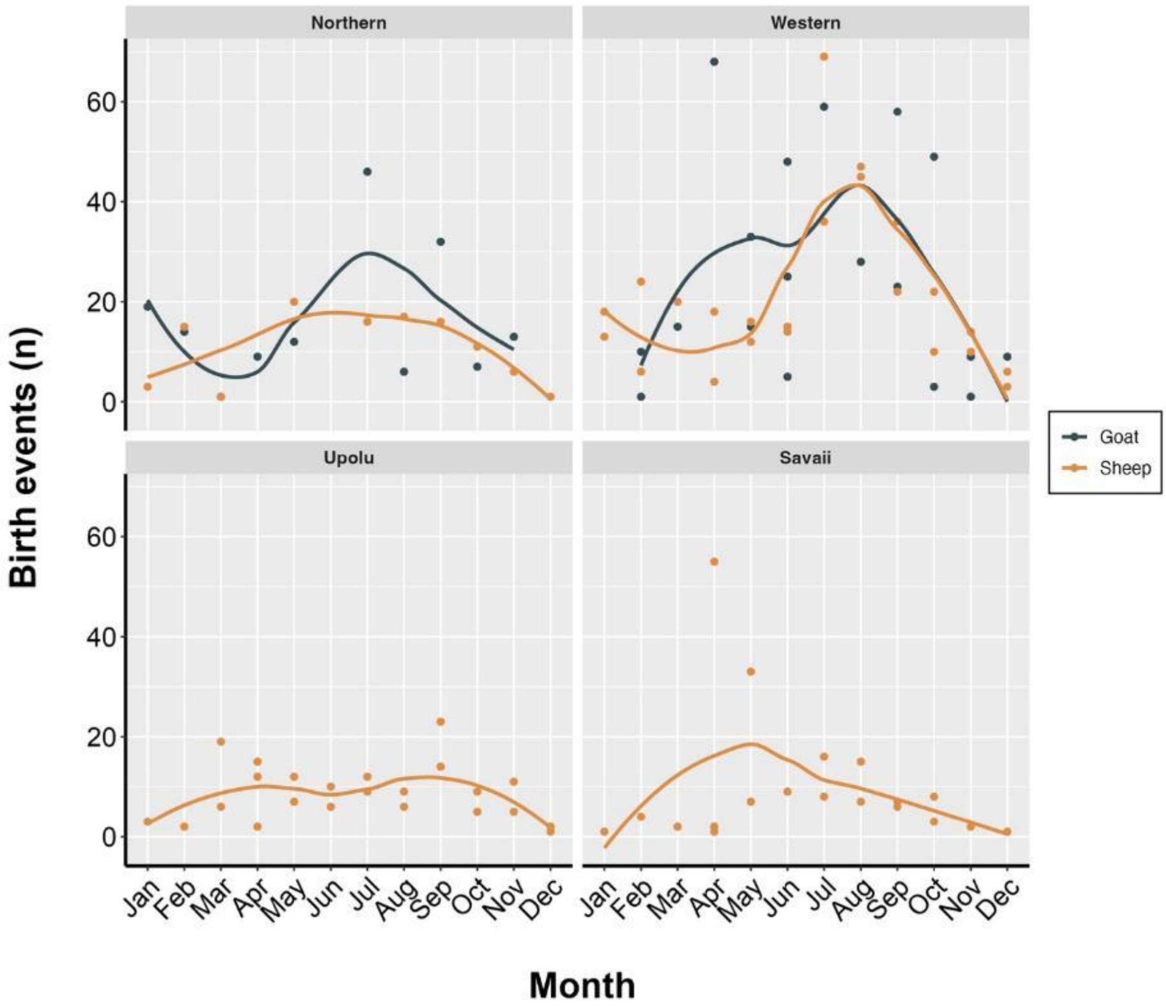

Figure 12: Distribution of births records (n=1,591) throughout the year in small ruminant farms in Fiji and Samoa.

The spread of birth events throughout the year leads to many sources of inefficiencies but is most likely caused by mismatching the nutritional requirements of reproductive females with pasture availability. In addition, having animals giving birth within a specific period makes it easier to identify females that have not given birth, concentrates care for newborns and have a defined yearly work schedule, for example when employing contract or temporary labour.

7.4.3 Losses of ewes and does

During the on-farm monitoring program we have recorded two types of losses for reproductive females: deaths and missing animals. Deaths were recorded every time when a carcass of a dead animal was found on the farm and missing animals were animals that were not present in the stocktake recording day which was conducted every 3 months. In some situations, animals would be recorded as “missing” in one stocktake but would “reappear” on the following recording event. In this situation the previous recording would be corrected in order to reflect the current status of the animal. A large variation in the proportion of missing reproductive females was observed across farm types and regions (Figure 13). In Fiji there was a tendency for a higher (P = 0.089) missing rate in farms in the Western compared to Northern Division and goats (P = 0.051) compared to sheep, but these differences did not reach statistical significance. The average proportion of reproductive females that went missing within a year varied from 9 to 28% with individual farms recording values as high as 36%. For this parameter, the lower value the better so Table 9 should be interpreted targeting a value lower than the ones presented in the 25th percentile column. The reason for such a high proportion of missing animals is unknown but it could be caused by the association of several factors including dog attacks and thefts. In addition, it's possible that a portion of missing animals were composed by animals that died or sold and were not properly recorded by the farmer. The data from Samoan farms were not included in the statistical analysis given that individual animal recordings were less complete than in Fiji so for these farms the losses (i.e. missing and mortality) were calculated over the total number of animals in each stocktakes. The distribution of the data is presented in Table 9.

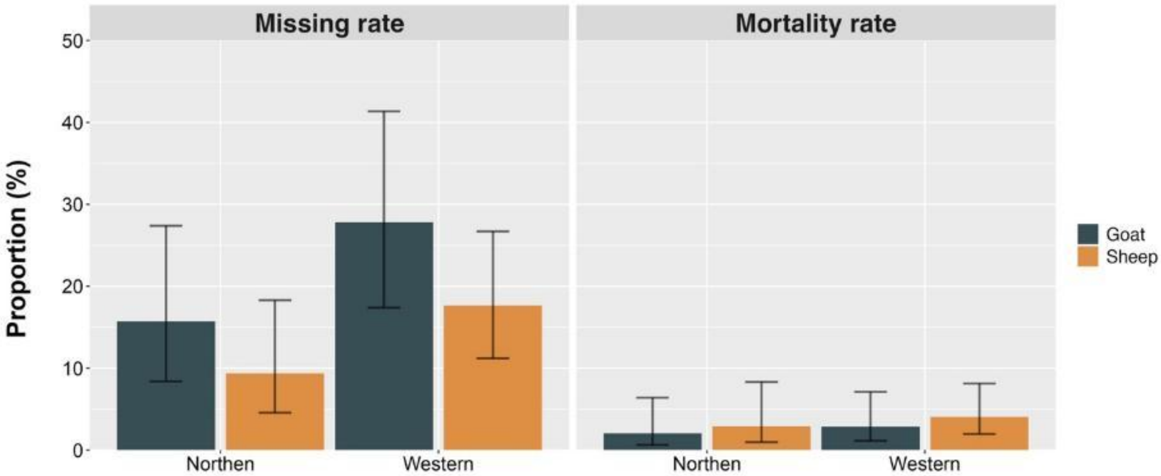

Figure 13: Effect of species and location on missing and mortality rate of does and ewes in Fiji. The logistic mixed-model regression used to investigate the missing rate presented a tendency for a significant effect for species (*P* = 0.051) and location (*P* = 0.089). For mortality rate the effect of species (*P* = 0.478) and location (*P* = 0.576) were not significant. Error bars represent the 95% confidence interval.

Dog attacks and thefts as possible causes for missing animals would partially explain why there is a tendency for higher rates in the Western division where farms tend to have greater proximity to villages and towns. There was also a tendency for a higher missing rate of goats compared to sheep which could be associated with a difference in grazing behaviour between these species or simply by a preference for goats by thieves. In any case, it seems clear that avoiding these loses would cause a huge impact in farm productivity. Arguably this impact would be bigger than any possible investment in technology aiming to improve productivity. The second cause of losses registered were deaths. In Fiji, the mortality rate across reproductive females was fairly similar across species and regions and none of the explanatory variables were significant (Figure 13). Overall, in Fiji, dam mortality across groups ranged from 2 to 4% which is fairly low considering the environment and management practices adopted. In New Zealand, researchers obtained data from four cohorts in three commercial farms over several lambing seasons observed an incidence of 6.3 to 6.9% while in the Caribbean this parameter varied from 8.1 to 11.8% (Mahieu *et al.* 2008; Flay *et al.* 2023). It would be expected that mortality rate of reproductive females in Fiji to be similar to the values observed in the similar environment and climate of the Caribbean region. It is possible, however, that a portion of animals classified as "missing" to be animals that actually died in the farm but were not correctly recorded. In Samoa, the mortality rate of reproductive females was comparable to the values observed in the literature, but the missing rate was much lower than values observed in Fiji. Given the smaller size of properties and flocks in Samoa, it's probably easier for farmers to have more control over the whereabouts of their animals, in addition would be easier for them to identify carcasses of dead animals over a smaller grazing area and therefore report it accordantly. The effect of missing and dead animals on the enterprise productivity is substantial. However, because dog attacks and theft are not easily controlled by farmers, it is imperative that other sources of inefficiencies are addressed on-farm. For example, maximising growth rate will shorten the time required for a young animal to reach saleable weight, therefore reducing their exposure to causes of mortality or losses by selling earlier.

Table 9: Distribution of missing and mortality rate data of reproductive females of small ruminant farms in Fiji and Samoa.

Species	Location	Missing rate (%)			
		25th percentile	Median	75th percentile	n of farms
Goat	Northern	12.8	15.8	20.5	4
Goat	Western	19.2	31.3	32.9	3
Sheep	Northern	4.1	4.4	11.0	3
Sheep	Western	9.9	20.8	28.3	7
Sheep	Upolu	0	0	6	7
Sheep	Savai'i	0	0	0	8
			Mortality rate (%)		
Goat	Northern	0	0	1.7	4
Goat	Western	2.4	4.8	7.1	3
Sheep	Northern	1.1	2.2	6.8	3
Sheep	Western	2.3	3.3	6.9	7
Sheep	Upolu	2.8	6.7	11.6	7
Sheep	Savai'i	0.0	10.8	15.6	8

7.4.4 Sales, home consumption and donations (gifts) of small ruminants

Throughout the project we have recorded that farmers have utilised small ruminants in three different ways, and these were: sold, household consumption and as a gift to others. In total, we have recorded 574 and 135 transactions in Fiji and Samoa respectively (Table 10). The distribution of this utilisation was very similar between species and locations, so we have grouped the data by country to be presented here. In summary, the great majority of the animals were sold followed by a smaller proportion that was utilised for home consumption and gifts. It's also interesting to note that utilisation was not affected by size of the farm which suggests that even farmers that are classified as "subsistence farmers" in Fiji would commercialize the majority of their animals.

Table 10: Utilisation of small ruminants recorded in 14 farms in Fiji and 16 in Samoa between 2022 and 2024.

Country	Usage	Proportion (%)	n of animals
Fiji	Gift	2.3	13
Fiji	Household meat	7.5	43
Fiji	Sold	90.2	518
Samoa	Gift	9.7	9
Samoa	Household meat	12.6	17
Samoa	Sold	80.7	109

The proportion of males utilised for sales, home consumption or gifts was slightly greater than females, in average males composed 58 and 59% of utilised animals in Fiji and Samoa, respectively. This could suggest that farmers would prefer to maintain some females in their heard and flocks in order to replace older ewes and does. The average liveweight (LW) in which animals were utilised by farmers was investigated by looking at the effect of location, species, sex, and type of utilisation. The results shows that species (P = 0.001) and sex (P = 0.01) were the only significant factors affecting LW. In average, sheep were heavier than goats and males were heavier than females when utilised for sales, home consumption or gifts (Table 11). Assuming that most of the commercialised animals would be slaughtered for meat consumption the LWs observed could be considerate low. In Australia, carcase weights for lambs are currently around 25 kg/head and 19.5 kg/head in New Zealand, while goat carcasses average 15 kg/head.

Table 11: Liveweight of small ruminants in Fiji and Samoa utilised for sales, home consumption or gifts.

Specie	Sex	Liveweight (kg)	SEM
Goat	Male	22.0	1.48
Goat	Female	19.9	1.57
Sheep	Male	29.6	1.36
Sheep	Female	27.6	1.42

The price received per animal is usually mostly influenced by factors such as liveweight, sex and breed. The pattern of prices paid in Samoa was different from Fiji, however the number of transactions recorded for Samoa (n = 135) is much lower compared to Fiji (n = 574) which makes it difficult to establish some comparisons across countries. Therefore, we analysed this trade for each country separately. In Fiji, we observed an interaction of LW and sex (P <0.001) affecting price. Interestingly, no effect of species (i.e. sheep or goat) or location was observed. The results predicts that males are "cheaper" at younger age than females but this trend changes as they grow older. Males are predicted to be born with a price (i.e. the intercept) of approximately FJ$64.2 and females FJ$102.3, however males are predicted to increase in value by 9.12 FJ$/kg and females by 6.1 FJ$/kg. Contrary to Fiji, in Samoa the price was only affected by LW but not by sex of the animal. In addition, the model predicts that in Samoa lambs are born with a higher value (WS$ 270/lamb) but have a lower increment in price with the weight gained throughout the growing period of W$T 2.4/kg.

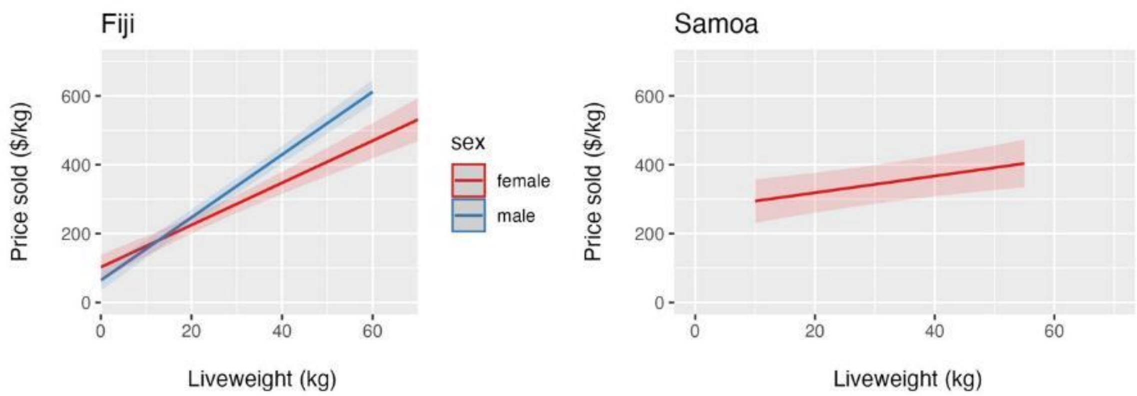

Figure 14: Relationship between price of commercialised small ruminants in Fiji and Samoa as a function of liveweight.

We have also looked at the effect of time of the year on prices. In order to do that prices were converted to Fijian dollars or Samoan tala per kilo of liveweight. The results show that in average, prices were stable throughout the year in the Northern Division of Fiji for sheep and goats and in the Western Division for sheep (Figure 15). However, goats sold for a much higher price per kilo on average for the months of January and December. These months coincide with the festivities season which helps to understand the increase in price. However, it's unknown why this effect is not detected for sheep, nor in the Northern Division. Interestingly, analysing the number of animals commercialised by months the number of goats sold in the Western Division shows a decline by the end of the year whereas sheep shows an increase (Figure 15). Looking through the data, we can see that the majority of the transactions for goats in Jan and Dec are coming from only one farm which have the highest averaging selling price for goats (20.8 FJ$/kg, n=43) as well as sheep (14.5 FJ$/kg, n=13) across all farms recorded. This farm is located approximately 150m from Queens Road between the population centres of Nadi and Lautoka which may provide a great strategic advantage in terms of commercialisation, especially during the festivity season.

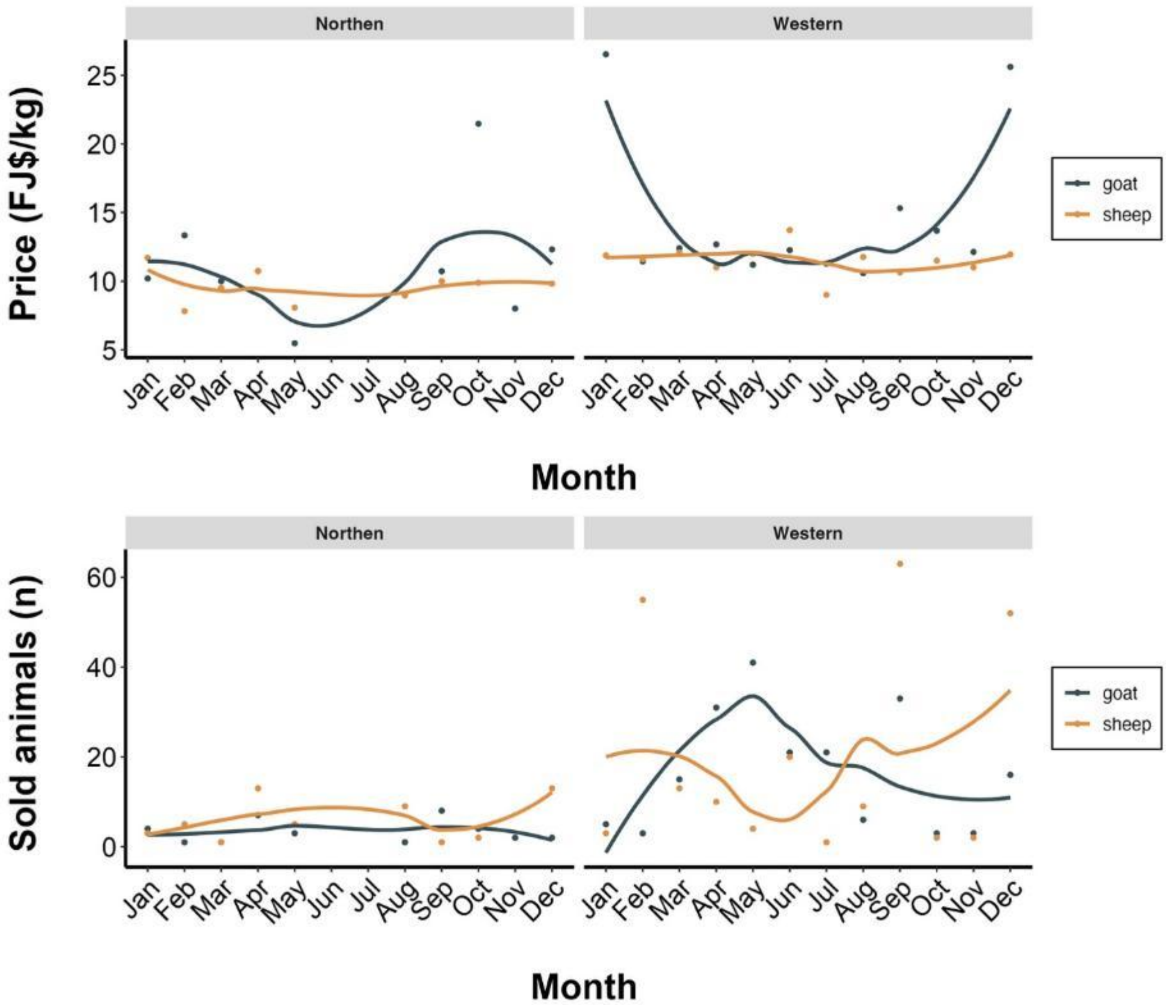

Figure 15: Average price per kilo and number of small ruminants sold by month in the Northern and Western Division of Fiji.

The average prices paid per animal and per kilo for small ruminants during the project are summarized in Table 12. It's interesting to note that there seems to be a large difference in price caused by sex for goats in Fiji while the same pattern cannot be identified in sheep. These prices can be considered relatively high, especially when comparing to what was being paid to farmers to some of the main exporters when this data was collected (Mid 2022 to Mid 2024). In New Zealand for example, the average price for lamb varied from approximately 8.5 to 6.5 NZ$/kg CW which if we consider a dressing percentage of approximately 45%, we have a variation from 5.2 to 4.0 FJ$/kg LW or 6.4 to 4.9 WS$/kg LW.

Table 12: Average price per kilo and head, liveweight of small ruminants sold during the project in monitored farms in Fiji and Samoa.

Country	Specie	Sex	Price/kg ($kg)	Price/head ($)	LW	n of animals
Fiji	Goat	Male	16.1	280	20.3	149
Fiji	Goat	Female	9.4	189	20.7	104
Fiji	Sheep	Male	11.2	324	29.4	131
Fiji	Sheep	Female	11.8	284	24.7	97
Samoa	Sheep	Male	13.6	379	31.6	67
Samoa	Sheep	Female	15.2	353	30.7	46

The trend of price per kilo as a function of liveweight followed a similar pattern in both countries but the larger number of observations registered in Fiji makes the visualisation easier (Figure 16). In Fiji, prices per kilo are very high for light animals and decrease sharply until reaching approximately 10$/kg at approximately 20kg LW when it seems to stabilize. In Samoa, the pattern is similar, but the restricted number of observations makes further generalisation more difficult. It seems, however there is a tendency in Samoa for further decreases in price (bellow the 10 $/kg mark) when animals are heavier than 40kg. In practical terms it's easier to understand that it wouldn't be common for animals to be commercialised at this liveweight range so this trend may not be of significance importance.

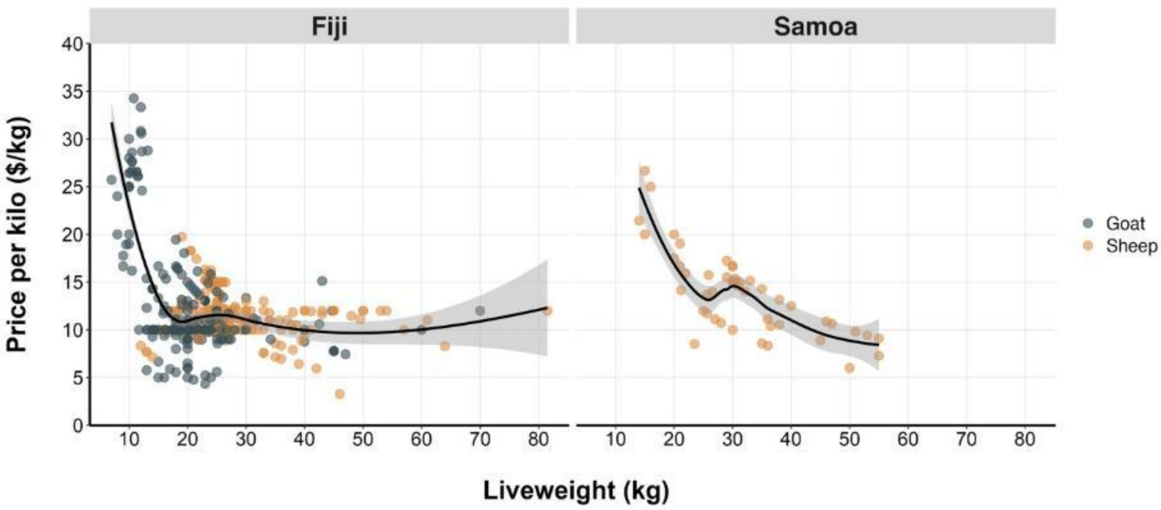

Figure 16: Price (FJ$ or WS$) per kilo of liveweight in response to different liveweights for sheep and goats commercialised in Fiji (n = 574) and Samoa (n = 135).

7.4.5 Gross income generated from small ruminants

The period which farmers consistently registered their sales varied from farm to farm and in order to standardize our comparisons we calculated the average monthly income by adding all sales recorded and divided by the number of days elapsed between the first and last recording and multiplying this value by the average number of days in a month. The same protocol was applied in order to calculate the monthly sales. The summary of the results is presented in Table 13. The results show a clear relationship between number of monthly sales and gross income. Interestingly, the top 75th percentile goat farms in the Western Division of Fiji presented almost double the gross income when compared to other farm types and locations, this is probably caused by a higher number of monthly sales as well as greater price per kilo, as presented in Table 12. There is also a large difference between farms in Upolu and Savai'i and it seems that farmers in the most populated (i.e. Western Division Fiji and Upolu) areas in both countries were selling more animals and therefore earning a greater gross income. However, sheep sales don't follow the same pattern with farmers in the Northern Division of Fiji earning a slightly higher income than Western Division.

Table 13: Monthly gross income and sales of small ruminant farms in Fiji and Samoa.

Specie	Location	Monthly sales (n)			
		25th percentile	Median	75th percentile	n of farms
Goat	Northern	1.1	1.4	1.6	4
Goat	Western	1.9	2.1	4.4	5
Sheep	Northern	2.3	2.7	3.0	3
Sheep	Western	1.2	1.3	1.9	4
Sheep	Upolu	0.6	1.4	1.8	6
Sheep	Savai'i	0.7	1.0	1.3	5
		Gross monthly income ($)			
Goat	Northern	240	290	354	4
Goat	Western	342	543	1,303	5
Sheep	Northern	584	653	746	3
Sheep	Western	411	585	717	4
Sheep	Upolu	219	445	717	6
Sheep	Savai'i	269	291	336	5

Across all farms recorded, the highest monthly gross income registered was for a sheep farm in the Western division of Fiji which commercialised on average 10.8 animals/month which resulted in an average monthly gross income of FJ$3,100.

7.4.6 Farm expenses

Associating costs related to production of small ruminants was challenging in these systems. The main reason is that all farmers had multiple activities in their properties and a better description of the characteristics of these farms is provided in section 7.1 of this report. We have noticed that especially in Samoa many farmers have recorded costs associated to payment of employees and fuel that were not only directly related to small ruminant production. Nevertheless, we will be presenting here all values reported as they were recorded by farmers. The proportion of the different type of expenses is presented in Figure 17. Interestingly, all four locations presented a very distinct pattern. In most locations the expenses were concentrated between one or two categories while in the Western division of Fiji the distribution was more homogeneous among a group of categories. As previously mentioned, the expenses in Samoa were mostly associated with salaries of employees (most farms were run by workers) and fuel. In the Northern Division of Fiji, approximately 65% of expenses were related to infrastructure which in most cases were costs associated with fencing or shed maintenance.

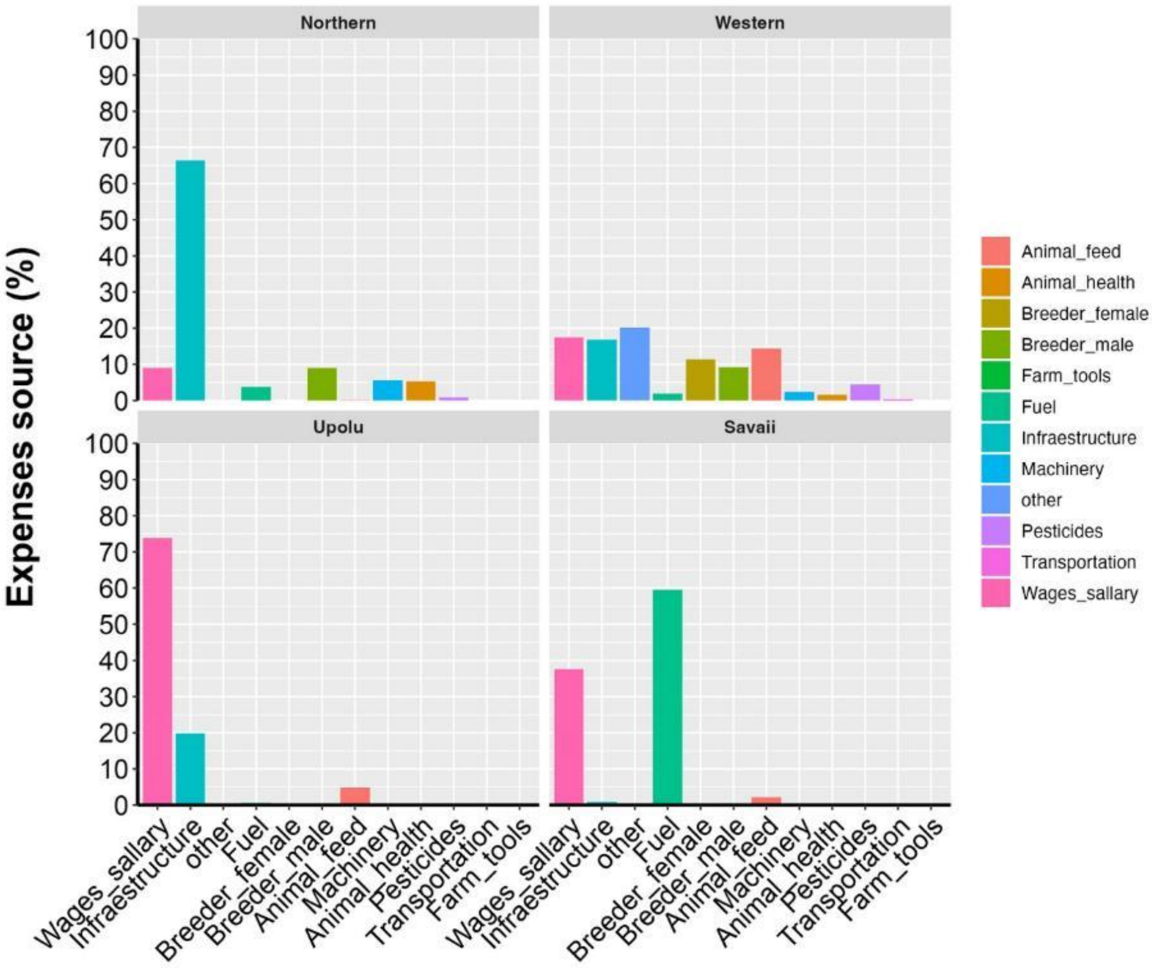

Figure 17: Source of expenses from small ruminant farms in Fiji and Samoa.

We have also calculated the monthly costs per head which takes into account the number of small ruminants raised over the period of time that the expenses were made. The monthly costs per head were likely overestimated in Samoa given the reasons previously mentioned, in particular attribution of 100 % of full-time employee salaries to the SR enterprise, when they are in fact used for multiple enterprises on the farm. The observed values for Fiji are likely to be closer to the reality of these farms, despite not considering the family labour utilised for rearing the animals. We recorded a value of 1.5 and 4.2 FJ$/head.month for farms in the Northern and Western Division of Fiji and 107 and 37.8 WS$/head.month for farms in Savai'i and Upolu.

7.4.7 Monthly net income of farms

The monthly income of farms was estimated based on the monthly income minus monthly expenditure. We were not able to calculate all parameters for all farms due to lack of complete records, but the data of the available farms are presented in Figure 18. It's clear that wages and fuel expenses are heavily affecting the results for Samoan farms where on average there was a negative net income of WS$ 869/month. As we previously mentioned farmers have recorded costs related to wages and fuel that were not directly related to small ruminant production. As we presented in section 7.1, the majority of Samoan farmers hired permanent employees to conduct the farm activities, which involved a diverse range of crops and livestock production. In Fiji, the farm jobs were mostly done by the farmers and family member with occasional hire of temporary employees to help with specific activities (e.g. fencing). These characteristics made easier for Fijian farmers to dissociate the out of pocket costs, especially labour, from other farm activities.

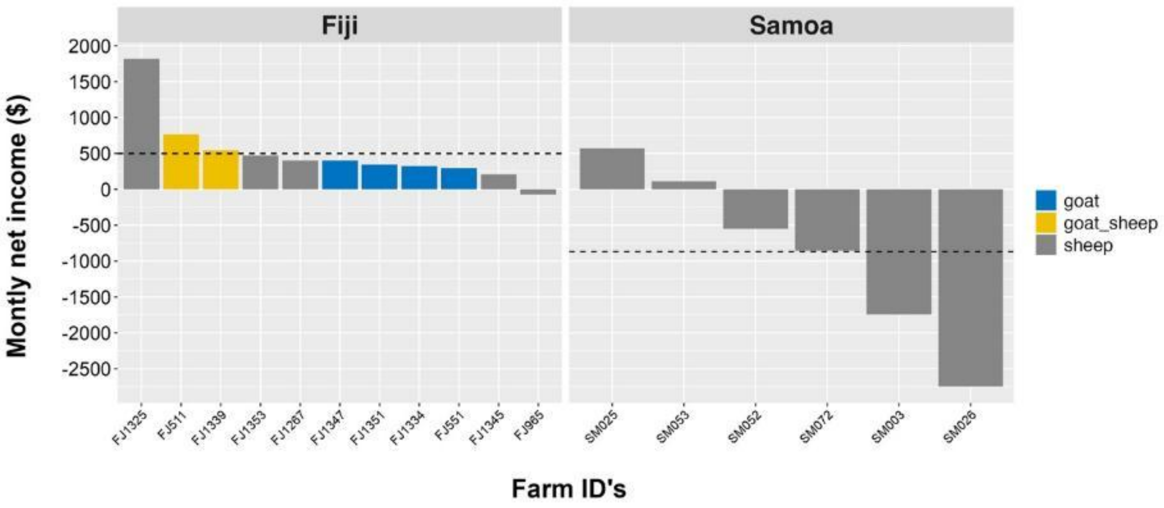

Figure 18: Monthly net income of small ruminant farms in Fiji and Samoa. Dashed lines represent the mean monthly net income for each country.

On average, Fijian farms had a monthly net income of FJ$ 499/month which would translate into FJ$ 5,988/year. However, a large difference can be observed between the "best" and "worst" farms. The farm with the highest income presented an average of FJ$ 1,817/month or FJ$ 21,804/year. Currently the minimum wage in Fiji is set as FJ$ 4.5/hour (FJ$ 9,360/year) so the income obtained from small ruminants is an important complement to the family earnings.

7.5 Anthelmintic resistance status of Fijian sheep and goat farms.

Sheep in the Western and Northern Division had average pre-treatment FEC of 1,676 and 1,312 epg (eggs per gram) respectively, whereas goats in the West and North had 2,100 and 372 epg, respectively. *Trichostrongylus* was found to be the most dominant genus, on average forming 43 and 33% of worm eggs in samples obtained from goats in the Northern and Western division, respectively. *Haemonchus* was the most common GIN genus affecting sheep in the Western (33%) and Northern division (35%). Overall *Strongyloides* was found to be the least common genus across all geographic divisions and host species followed by *Oesophagostomum* which varied from 17 to 29%.

Albendazole had the lowest overall average efficacy of the anthelmintic treatments (65% FEC reduction, FECR), followed by LEV (91% reduction), ALB+LEV (94% FECR), IVM (97% FECR) and MOX (99% FECR, Figure 19). Some small variation in treatment efficacy was observed when comparing between the different host species and farms, however the results were similar across sheep and goats (Table 14).

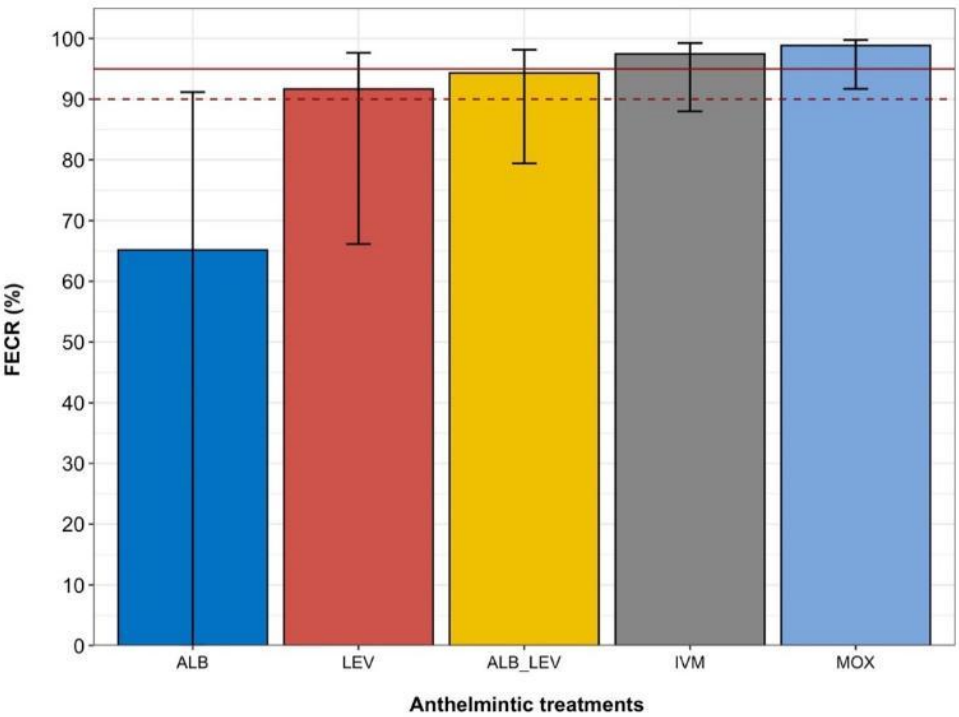

Figure 19: Mean faecal egg count reduction (FECR) of anthelmintic treatments administered to sheep and goats in the Western and Northern division of Fiji. Means were calculated across all farms (n=11) and hosts species (n=2) included in the study. Error bars represent the mean upper and lower 95% confidence interval of each treatment. Solid and dashed lines marks 95 and 90% FECR, respectively. Albendazole (ALB); Levamisole (LEV); Ivermectin (IVM); Moxidectin (MOX).

Anthelmintic resistance to ALB was present in all 4 goat farms where ALB was tested (51, 58, 72 and 84% FECR) as well as in two out of three sheep farms (3 and 89% FECR) while only one flock was classified as susceptible to this drug (100%; Table 14). The results for LEV showed that worms on three (95, 97 and 100% FECR) out of the four goats farms were classified as susceptible to LEV, however resistance was detected in one goat property (80%; Table 14). Levamisole had a lower efficacy in sheep than in goat farms. Two out three flocks were resistant (81 and 88% FECR) to LEV and one was classified as suspected resistance (98% FECR) given the lower 95% confidence interval being below 90% (Table 14).

As expected, the combination of LEV+ALB had higher efficacy than the two active ingredients applied separately (Table 14). All four goat herds (95, 99, 100, 100% FECR) where the ALB+LEV combination treatment was tested were found to be susceptible (Table 14). However, one sheep flock was detected as resistant (69% FECR) to the combination treatment while the other two flocks were classified as suspected resistance and susceptible (96.2 and 100% FECR). Resistance to IVM was detected only in one goat herd (93% FECR) while the other three were susceptible to this drug (95, 97, 100% FECR). None of the sheep flocks were resistant to IVM however one flock presented suspected resistance (FECRT: 98% and 88% CI) and the other two were susceptible (100 and 100% FECR). Moxidectin was the treatment that presented the highest efficacy. In addition, no goat herds (100 and 100% FECR) or sheep flocks (99, 100 and 100%) were resistant to this drug (Table 14). Nevertheless, two goat herds were classified as suspected resistance to MOX (96 and 96% FECR) given the lower 95% confidence interval being below 90% FECR. Closantel presented very low efficacy in reducing FEC in both sheep (0, 38 and 81% FECR) and goat (25, 52, 76 and 79% FECR) farms (Table 14). This not surprising as it is a narrow spectrum anthelmintic with efficacy claims only against *Haemonchus*.

Table 14: Summary of faecal egg count (FEC), faecal egg count reduction (FECR); 95% confidence interval (CI) and number of farms in each anthelmintic resistance (AR) status category of sheep and goat farms in the Northern and Western division of Fiji.

	Anthelmintic treatments											
	ALB[A]		LEV		ALB+LEV		IVM		MOX		CLO[C]	
	Goat	Sheep	Goat	Sheep	Goat	Sheep	Goat	Sheep	Goat	Sheep	Goat	Sheep
FEC day 14 (epg)												
Mean	413	154	55	47	25	53	45	10	37	1	589	619
Maximum	766	414	85	87	90	142	80	30	83	5	1655	1435
Minimum	56	0	0	6	0	0	0	0	0	0	150	144
FECR (%)												
Mean	62.2	63.8	93.4	89.4	98.6	88.6	96.5	98.7	98.2	99.8	58.7	39.9
Maximum	83.9	100	100	98.6	100	100	100	100	100	100	79.8	81.7
Minimum	50.9	2.52	80.9	81.3	95	69.5	93.1	96.2	96.2	99.4	25.3	0.0
95% C.I (%)												
Mean upper	91.3	91	98.3	96.8	99.3	96.6	99	99.6	99.6	100	87.8	85.2
Mean lower	-52.2	-47.1	69.1	62.2	94.2	59.7	83	94.6	88.1	96.5	-47.0	-149.6
AR status (n)[B]												
Resistant	4	2	1	2	0	1	1	0	0	0	NA	NA
Suspected	0	0	0	1	0	1	0	1	2	0	NA	NA
Susceptible	0	1	3	0	4	1	3	2	2	3	NA	NA

[A]Albendazole (ALB); Levamisole (LEV); Ivermectin (IVM); Moxidectin (MOX); Closantel (CLO); [B]Represents the number of farms in each anthelmintic resistance status classification; [C]CLO is a narrow spectrum anthelmintic with efficacy claims only against *Haemonchus*.

Overall, the results obtained suggests that despite some level of resistance was observed for the drugs which have been most utilised over the last decades (i.e. ALB and LEV) the level of resistance encountered is lower than what was expected based on previous reports. Suggestions and recommendations on how to manage the current level of anthelmintic resistance were elaborated based on the results and delivered as a report to the Fijian Ministry of Agriculture (Appendix 5: Resistance status of six anthelmintic treatments in Fijian sheep and goat farms.).

7.6 The production impact of ineffective gastrointestinal nematode control in Fijians small ruminant systems.

The results obtained show that reproductive females treated were in average 1.8kg heavier (P = 0.0002) than control group and ewes were 4.8kg heavier (P = 0.002) than does (Table 15). There was no difference (P = 0.8545) in FEC across species but treated animals presented lower (P < 0.0001) FEC than control group. Treated group presented a higher BCS and FAMACHA score compared to control group (P < 0.005).

Table 15: Liveweight (lsmeans ± sem), faecal egg count (FEC), body condition score (BCS) and FAMACHA score of reproductive female sheep and goats subjected to eradication treatment of gastrointestinal nematodes or common farm practices in Fiji.

	Goats		Sheep		*P*-Value Treat	*P*-Value Specie
	Control	Treat	Control	Treat		
Liveweight (kg)	32.2 ± 1.58	34.1 ± 1.58	37.1 ± 1.62	39.0 ± 1.61	0.0002	0.002

FEC (epg)	586.1 ± 1.46	6.50 ± 1.46	638.2 ± 1.49	1.47± 1.47	<0.0001	0.8545
BCS	2.45 ± 0.11	2.65 ± 0.11	2.69 ± 0.11	2.89 ± 0.11	<0.0001	0.0114
FAMACHA	3.36 ± 0.11	3.59 ± 0.11	3.81 ± 0.11	4.04 ± 0.11	<0.0001	<0.0001

Despite the significant lower FEC for the Control groups, the level of worm burden was much lower than what was expected as well as initially recorded during the baseline survey (Section 7.1). The cause for the lower than expected worm burden is unknown. In this trial we have limited the proportion of treated animals to a maximum of 20% of the total flock or herd which has been successfully adopted previously (Kelly *et al.* 2010). This is because treated animals could be reducing the population of infective parasites in the environment and therefore affecting the exposure of control animals. Alternatively, the presence of the field officers frequently visiting the farms could have brought more awareness in regards the control of gastro-intestinal nematodes leading farmers to drench their animals more frequently than before.

The proportion of missing reproductive females (i.e. does and ewes) demonstrated to be surprisingly high whereas mortality rate is below expected (Table 16). It's possible that some missing animals are dead animals that have not been appropriately recorded. The investigated factors did not show any significant effect on the parameters analysed. However, there was a tendency for a higher missing rate (18.0 *vs* 11.6; $P = 0.056$) for the Control group when compared to the Treatment group. In general, the proportion of sold females was fairly low for all groups which indicates a possible problem with culling. In most farms included in this program, farmers do not have a defined culling strategy. The consequences of that are that farmers are spending capital to maintaining in their herds and flock's unproductive animals. Reproductive females become less fertile and more likely to loss as they get older. The age at which ewes and does start declining in productivity varies depending on the environment that they are exposed to as well as their genetics, but in general you could expect some decline in fertility around 4-6 years of age (Mullaney and Brown 1969). In this study the overall rate of sold females was approximately 4% which means that would take 25 years for all reproductive females within a herd/flock to be replaced at this rate.

Table 16: Effect of long-acting anthelmintic treatment on the proportion of ewes and does missing, sold or dead within one year.

	Treatment		**Species**		**Location**		*P*-Value Treat	*P*-Value Specie	*P*-Value Location
	Control	Treat	Goats	Sheep	West	North			
Missing rate (%)	18.0	11.6	15.4	14.6	16.1	13.1	0.056	0.644	0.994
Mortality rate (%)	4.3	2.7	3.5	3.3	5.2	2.3	0.334	0.918	0.167
Sold (%)	4.0	2.1	3.5	2.4	4.6	1.8	0.211	0.474	0.197

Based on the reproductive parameters assessed, and contrary to our initial hypothesis, suppressing gastrointestinal nematode in the treatment group did not improve reproductive performance in sheep or goats (Table 17). The results also did not show any significant effect ($P > 0.05$) for small ruminants' species or location. Overall, the results demonstrated low reproductive efficiency when compared to improved tropical production systems under similar conditions but still within range of values reported in the literature (Alexandre *et al.* 2001). Probably the most limiting parameter presented is the conception rate which represent the proportion of reproductive females giving birth within a year. This parameter could be expected to be close to 95% under improved situations. We have observed an overall average of 72.5% for conception rate across this trial which could be potentially caused by a large number of females not getting pregnant, by a significant occurrence of abortions or both.

Table 17: Effect of long-acting anthelmintic treatment on reproductive performance of ewes and does.

	Treatment		Species		Location		*P*-Value Treat	*P*-Value Specie	*P*-Value Location
	Control	Treat	Goats	Sheep	West	North			
Conception rate (%)	72.6	74.1	75.3	71.4	70.8	75.8	0.764	0.428	0.323
Litter size (n)	1.2	1.3	1.3	1.1	1.3	1.2	0.432	0.308	0.543
Lambing/kidding rate (%)	96.6	87.0	99.4	84.5	91.6	91.7	0.364	0.176	0.993

We have also investigated the effect of supressing gastrointestinal infection in ewes and does on birth weight and growth performance of their offspring. The results obtained no effect of treatment on birth weight (2.29 *vs* 2.31kg; $P = 0.775$). The most significant factor affecting birth weight was type of birth with singles, twins and triplets showing a decrease in weight (2.7 *vs* 2.4 *vs* 1.7kg; $P < 0.001$) with litter size as expected. Lambs showed a tendency to be born heavier than kids but this did not reach statistically significance (2.34 *vs* 2.24; $P = 0.064$). Interestingly, location also had a significant effect of birthweight of newborns in the Western Division were heavier when compared to the Northern Division (2.4 *vs* 2.1kg; $P < 0.001$). The difference in birthweight between locations is hard to understand given that overall performance of farms for all other parameters seems to be similar across the two regions. The growth performance of offsprings was analysed in order to identify any possible treatment effect. The results obtained are presented in Figure 2.

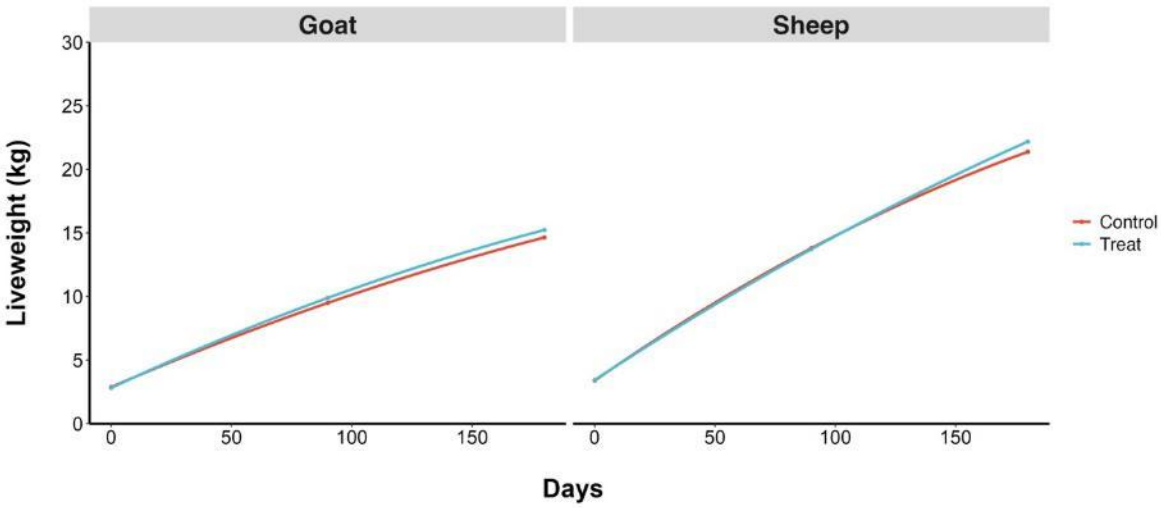

Figure 20: Liveweight of lambs and kids born from females treated with long-acting anthelmintics in order to suppress gastrointestinal infection (Treat) or normal farm routine (Control).

The liveweight gain of kids and does was not different between the treatment groups ($P > 0.05$), the average LWG from birth up to 90 days was in average 115 g/head.day for lambs and 76 g/head.day for kids. The expected LW at 90 and 180d would be approximately 9.7, 15.1kg and 13.7, 21.8 kg for kids and lambs respectively. Mahieu *et al.* (2008) reported LW's of 16.7 to 10.6kg at 70-day age for Martinik lambs raised in improved systems in the Caribbean and from 6.9 to 7.9 for Creole goats raised in similar conditions. The values we observed for sheep (11.5 to 11.7 kg at 70-day age) in this study are in the lower range of the reported by the previously mentioned author, but the goat's performance is above (8.1 to 8.4 kg at 70-day age) of the range.

7.7 The effect of long-acting drenches on peri-parturient ewes and does as well as on its offspring's

Overall, the long-acting anthelmintic treatments tested did not affect FEC, liveweight of dams, birthweight of kids and lambs nor kidding and lambing rates. The analysis of the faecal samples showed that surprisingly there was no effect of treatment on FEC ($P = 0.141$) but a significant effect for species that showed that goats presented an overall higher FEC than sheep (680 vs 171 epg; $P < 0.001$). After birth, does lost on average 2.8 kg LW between July and October while ewes lost 7.4 kg (Figure 21). There was no significant ($P = 0.785$) effect for treatment on liveweight of both species, however there was a significant effect for date ($P < 0.001$) and species ($P = 0.001$).

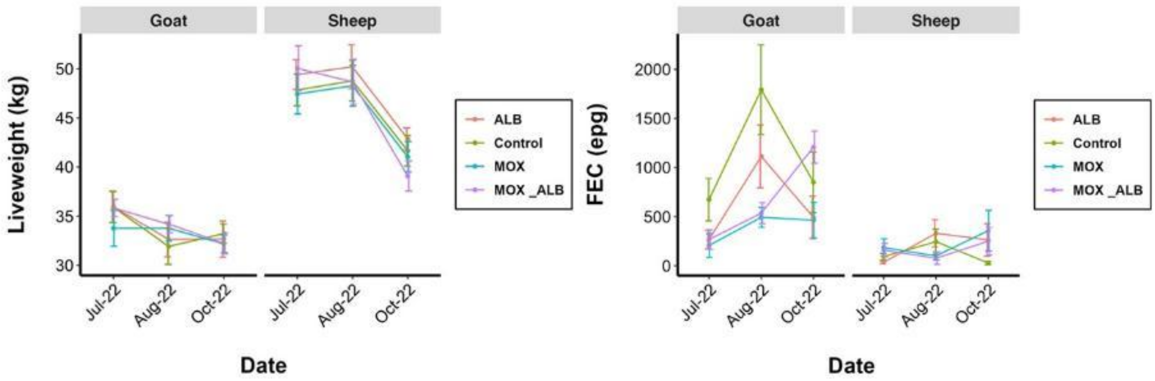

Figure 21: Liveweight and faecal egg count (FEC) of peri-parturient ewes and does treated with different combinations of long-acting anthelmintics. All treatments were applied in early July on the same day as the initial sampling date.

The anthelmintic treatments also didn't cause any effect on birthweight of lambs and kids. A significant effect for species ($P < 0.001$), type of birth (i.e. single or twins; $P < 0.001$) and sex ($P = 0.046$) was observed and is summarized in Table 18. In relation to the conception rate, we did not observe any significant effect ($P > 0.05$) of treatment groups or species. The average conception rate was 76.7% for ewes and 73.3% for does and when separated by treatment groups the following averages were observed: 73.3, 76.7, 76.7 and 73.3% for ALB, Control, MOX and MOX + ALB. The results suggest a possible existence of some level of anthelmintic resistance in both research farms. This could be possible because despite not being commercially available the two drugs utilised in this trial (i.e. moxidectin and albendazole), have been previously utilised in these research stations.

Table 18: Mean birthweight, lower and upper 95% confidence interval of lambs and kids born of ewes and does treated with different long-acting anthelmintics.

Species	Sex	Type of birth	Mean LW (kg)	95% LCI (kg)	95% UCI (kg)
Sheep	Male	Single	3.9	3.6	4.1
		Twin	3.1	2.7	3.5
	Female	Single	3.7	3.4	3.9
		Twin	2.9	2.5	3.3
Goat	Male	Single	3.1	2.8	3.4
		Twin	2.3	2.0	2.7
	Female	Single	2.9	2.6	3.1
		Twin	2.1	1.8	2.4

7.8 Field test of creep feed supplementation on lamb performances at Nawaicoba Quarantine Station.

The intake of creep feed increased throughout the trial (Table 9). Lamb performance results are shown in Table 19. There were no lamb mortalities in the group having access to creep supplement whereas the control group had a 4.6 % mortality rate. Mean liveweight gain in the creep-fed group was 188 g/day, compared to 168 g/day for the Control group, with total weight gains of 25.1 kg and 22.5 kg, respectively.

Table 19: Description of creep-feeding intake by experimental week.

Week	Start and end date	Animal intake (g/head/day)	Animal intake (%LW/day)
1	18/08/22 - 24/08/22	59	0.74
2	25/08/22 - 30/08/22	75	0.79
3	01/09/22 - 07/09/22	47	0.42
4	08/09/22 - 14/09/22	55	0.45
5	15/09/22 - 21/09/22	50	0.38
6	22/09/22 - 28/09/22	61	0.39
7	29/10/22 - 05/10/22	91	0.51
8	06/10/22 - 12/10/22	116	0.65
9	13/10/22 - 19/10/22	164	0.84
10	20/10/22 - 26/10/22	244	1.11
11	27/10/22 - 02/11/22	258	1.12
12	03/11/22 - 09/11/22	265	1.04
13	10/11/22 - 16/11/22	276	1.04

A simple cost-benefit analysis was conducted and is presented in Table 20. The ingredients selected for the creep feeding diet were not necessarily the cheapest options available but were the ingredients which had more nutritional data available and consistency in quality. It's a common situation where not well-known by-products are utilized based on price solely, and the variability in batch quality can affect the results of the supplementation. The extra costs related to supplementation here didn't consider the extra labor cost for feeding these supplements or the infrastructure necessary in order to limit the access of ewes to the supplement. Overall, the cost of supplementation was FJD$ 19.4 per head given the consumption of 12.3kg of supplement from birth till weaning. The extra gain in liveweight observed was of 2.6kg/lamb which would provide a return of FJD$ 31.2 based on average prices. In this sense, the margin per animal would be of FJD$11.8/lamb which is significant when taking into consideration the amount of capital invested (i.e. FJD$19.4). In this analysis we also did not consider a lower mortality rate of the supplemented group which would make the benefit of creep-feeding even more advantageous.

Table 20: Cost-benefit analysis of creep-feeding supplementation for lambs from birth until weaning at 90 days old.

Group	Supplement intake 90d (kg/head)	Cost supplement 90d (FJD$/head)	LW difference (kg)	Return (FJD$)	Margin (FJD$)
Control	0	0	0	0	0
Treatment	12.3	19.4	2.6	31.2	11.8

Overall, the results suggest a significant benefit of providing creep-feeding supplementations to lambs from birth until weaning. The practically of this practice needs to take into consideration the usual infrastructure and practices existent in commercial farms. For instance, this study was conducted in a research station where the animals do not return to an animal house at night which is not the case for most Fijian and Samoan farmers. In addition, in this study we utilised lambs that were born out of a fixed joining season, a practice which is not common on Fijian or Samoan farms and produces a more homogeneous group of lambs in terms of age and liveweight. One possible way to overcome these differences would be to include a separate section of the animal house where the creep-feeding supplement could be offered. In this way, lambs would have free access to the supplement at night when are returned to the animal house. The costs of the infrastructure and labour required for implementation on private farms needs to be assessed on-farm.

7.9 Growth performance and puberty attainment of two different genotypes of replacement ewes supplemented post-weaning.

As expected, supplemented lambs presented a significant higher (86 vs 62 g/head.day; $P < 0.001$) liveweight gain (LWG) than control group from the start of the trial until joining with rams at the beginning of May. Interestingly, purebred Fiji Fantastic (FF) lambs grew faster than F1 lambs (79.5 vs 68.7 g/head.day; $P = 0.018$). The difference in LWG observed between the genotypes was likely caused by some differences in adaptation just after weaning: There was no significant difference in LW when the groups were selected at weaning (17th of October), however when the trial started (27th of November) F1 lambs were already significantly heavier than FF lambs (24.9 vs 23.0 kg; $P = 0.001$). However, as previously mentioned, FF lambs had a higher LWG throughout the trial and reached joining period with similar liveweight to F1 lambs (33.6 vs 33.2 kg; $P = 0.33$) but supplemented lambs were approximately 4kg heavier than the control group (35.3 vs 31.5 kg; $P < 0.001$; Figure 22) for both genotypes.

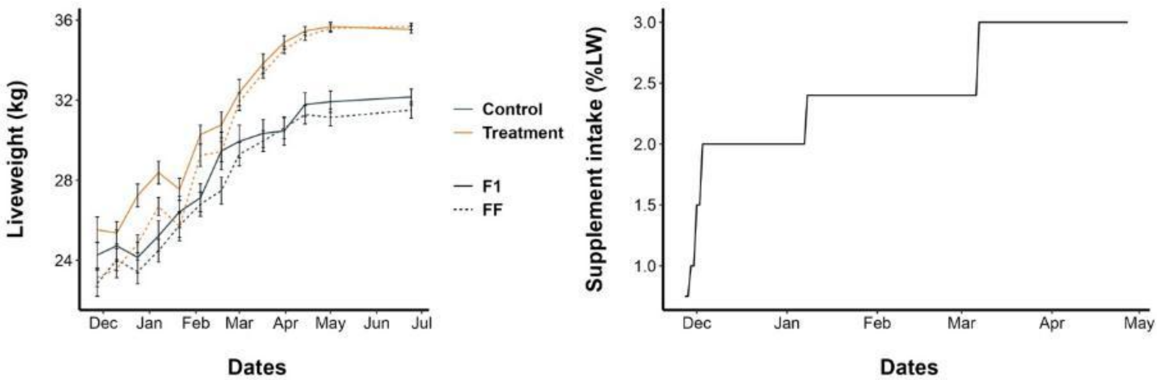

Figure 22: Liveweight of F1 and FF lambs supplemented through the growing period. Data presented are the arithmetic means for each point in time and error bars represent the standard error of the mean. Supplement intake of treatment group throughout the experimental period.

All replacement ewes achieved puberty within the period between the 4th of May and 14th of June when they were on average 285 to 326 days old. Supplemented ewes reached puberty earlier than control group as demonstrated in Figure 23. Is not known if this difference would have led to a lower pregnancy rate for the control group if they have been mated but this is possible. It has been suggested that reproduction efficiency of farms is enhanced when replacement ewes are able to attain puberty within their first year of life (Wall *et al.* 2018).

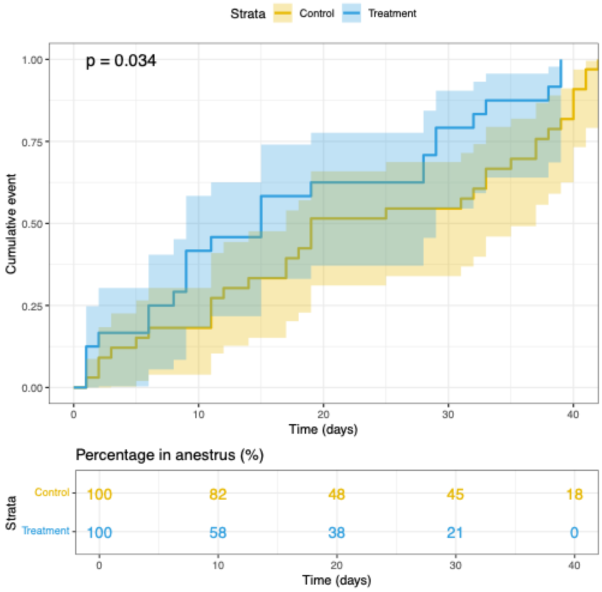

Figure 23: Analysis of the effect of post-weaning supplementation of replacement ewes on interval to puberty attainment with proportion of flock attaining puberty (first observation of oestrus, cumulative event).

A cost-benefit analysis was conducted simulating that these animals would be sold for meat at the end of the supplementation period (Table 21). The results show that, if these females were going to be sold for meat the cost of supplementation would not have been economical for farmers. Each female would have provided a negative margin of FJD$ 67.6 loss per animal. However, if these animals were to be utilised for reproduction, a higher pregnancy rate on the first year would be necessary to make the investment in supplementation economical. Considering the estimated negative margin per ewe and a flock of 100 ewes, the total economic deficit would be of FJD$ 6,760. Using an average selling price of a weaner lamb of FJD $ 200 would mean that the lambing rate for the treatment group would need to be 33.8 percentage points greater than the control group in order to cover the supplementation costs. This outcome is very unlikely given that the final LW difference between the two groups was approximately 4kg. In summary, both analyses suggests that supplementing replacement ewes after weaning might not be economically useful in Fiji at the moment given the costs and market scenario. In addition, it's interesting to notice that these analyses did not provide any indication of a better performance of F1 (Dorper x Fiji Fantastic) when compared to the pure FF (Fiji Fantastic). This observation highlights that investments in genetic merit can be eroded by environmental, health and nutritional limitations.

Table 21: Cost-benefit analysis of supplementation of replacement ewes from weaning until joining.

	Final LW (kg)	Supplement intake (kg/head)	Supplement (FJD$/head)	LW difference (kg)	Return (FJD$)	Margin (FJD$)
Control	31.5	0	0	0	0	0
Treatment	35.3	113.2	172.63	3.8	45.6	-67.6

7.10 An agronomic assessment of two cultivars of Juncao grass compared to Guatemala and Elephant grass in a tropical environment: the effect of pre-harvest canopy height on yield and nutritive value.

Juncao grass has been promoted as a high productivity and nutritional value plant to be utilized for livestock production in tropical countries (Yuan 2019; Zheng et al. 2023). However, there is currently a lack of scientific evidence to support claims of high productivity or nutritional value as well as basis for management recommendations such as harvest frequency. In this study, we aimed to compare production and nutritive value of two cultivars of Juncao grass to two tropical fodder species common worldwide - Guatemala and Elephant grass. In addition, we also looked at the effect of four different harvest frequencies established as pre-harvest canopy heights on these parameters. The results showed that increments in pre-harvest canopy height led to greater biomass per harvest and longer periods of harvest interval, yielding a similar yearly production when these plants are harvested between 1 to 2 m of pre-harvest canopy height. Juncao cultivars produced more biomass than Guatemala and Elephant grass, but this difference was mostly evident in Year 1. Interestingly, nutritional and mineral concentration parameters were more affected by forage species than by pre-harvest canopy heights. Guatemala grass had the lowest and Elephant grass the highest nutritive value and mineral content while the Juncao cultivars tended to be similar to Elephant grass. The information obtained with the present work suggests that both Juncao cultivars are a good forage option for livestock producers in tropical areas. However, the high yielding characteristic of these plants might be depended on high levels of fertilization/soil fertility in order to maintain sustainable levels of production throughout the years, and in the absence of high inputs, their productivity and nutritive value may be affected. This should be taken into consideration when recommending the adoption of this fodder by livestock farmers in developing countries who usually have limited access to fertilizers. Based on the estimated yearly nutrient extraction obtained in this study, it could be suggested that yearly fertilization requirement for Juncao cultivars to be approximately 256.9 kg of N ha^{-1}, 92.3 kg of P ha^{-1}, 64.7 kg of K ha^{-1}, 90.8 kg of Ca ha^{-1} and 51.1 kg Mg ha^{-1}. It's important to understand however that these values will be affected by several factors such as yearly yield and soil initial fertility level, nevertheless it can be utilised as a guidance in similar environmental scenarios where this information is lacking. Juncao green and purple should be harvested when pre-harvest canopy height reaches between 1 to 2 m, the lowest values of this range will favor greater nutritional value while higher targets will promote greater biomass production per harvest.

Biomass produced per harvest was significantly affected by species, pre-harvest canopy height, production year and its interactions (Table 22) and significantly increased with increments in canopy heights up to 1.5 m, when it stabilized. There was no further gain in biomass with further canopy growth to 2 m (Table 22). There was no difference between species in production per harvest when harvesting at 0.5 or 1.5m. There was an interaction between fodder species and production year in average biomass production such that both Juncao cultivars significantly reduced production ($P < 0.0001$; not shown) from Year 1 to 2 while Guatemala and Elephant grass were not different ($P > 0.05$; not shown) across years. Nevertheless, both Juncao cultivars still produced more ($P < 0.05$) biomass per harvest than Elephant grass in both production years. There was no difference in production per harvest when plots were harvested at 1.5 or 2.0 in both production years, but when harvested at these heights, plots produced more ($P < 0.05$) than when harvested at 0.5 or 1.0m during the whole experimental period.

Table 22: Biomass per harvest, harvest interval and yearly yield of Elephant grass, Guatemala, Juncao green and Juncao purple harvested at four different canopy heights over two production years.

	Harvesting height					Production year			Mean	SEM
	0.5	1.0	1.5	2.0		Year 1	Year 2			
Biomass per harvest (t of DM ha^{-1})										
Elephant grass	0.5	2.8	4.7	4.5		3.7	2.6		3.2**a**	0.2
Guatemala	0.3	2.1	6.1	6.5		4.3	3.3		3.8**a**	0.2
Juncao green	0.9	4.1	5.5	10.0		6.4	3.8		5.2**b**	0.2
Juncao purple	0.9	4.6	6.9	8.7		6.2	4.4		5.3**b**	0.2
Mean	0.7**a**	3.4**b**	5.8**c**	7.5**c**		5.1**a**	3.6**b**			
Harvest interval (days)										
Elephant grass	43.2	74.0	104.3	111.0		75.5	90.7		83.1**ab**	2.7
Guatemala	47.7	71.6	112.1	141.7		85.4	101.2		93.3**b**	3.0
Juncao green	42.6	64.6	97.8	125.1		73.0	92.1		82.5**a**	2.6
Juncao purple	41.0	64.7	80.3	111.5		69.2	79.5		74.4**a**	2.5
Mean	43.6**a**	68.7**b**	98.6**c**	122.3**d**		75.8**a**	90.9**b**			
Yearly biomass yield (t of DM ha^{-1})										
Elephant grass	3.9	13.7	14.2	13.6		14.0	8.7		11.4**a**	1.5
Guatemala	2.7	11.6	19.9	13.0		12.8	10.8		11.8**a**	1.5
Juncao green	7.7	22.6	19.8	26.9		26.7	11.9		19.3**b**	1.5
Juncao purple	8.2	24.1	28.1	25.9		26.1	17.1		21.6**b**	1.5
Mean	5.6**a**	18.0**b**	20.5**b**	19.9**b**		19.9**b**	12.1**a**			

[1] Biomass per harvest, SP P<0.001, HH *P*<0.001, PY *P*<0.001, SPxHH *P*<0.001, SPxPY *P*=0.005, HHxPY *P*=0.001; Harvest interval, SP P<0.001, HH *P*<0.001, PY *P*<0.001, SPxHH *P* = 0.049, SPxPY *P*=0.627, HHxPY *P*=0.01; Yearly biomasss yield SP P<0.001, HH *P*<0.001, PY *P*<0.001, SPxHH *P* = 0.156, SPxPY *P*=0.002, HHxPY *P*=0.187.

Annual yield was significantly affected by fodder species, canopy height at harvest, production year and the interaction between fodder species and production year (Table 222). Harvesting all four fodder species at 0.5 m reduced (*P* < 0.0001) biomass production when compared to the other pre-harvest canopy heights. Also, a large reduction in annual yield was observed when comparing Year 1 and Year 2 (19.9 vs 12.1 t of DM ha^{-1}; *P* < 0.0001). Overall, both Juncao cultivars (i.e. green and purple) had higher yearly yield compared to Guatemala and Elephant grass across both years (Table 22). However, the interaction between fodder species and production year demonstrated that this difference was mainly due to a higher production in Year 1 compared to Year 2 . Both Juncao cultivars produced a higher yield (*P* < 0.0006; not shown) in Year 1 when compared to Year 2. In addition, Juncao cultivars in Year 1 were more productive than Guatemala (*P* < 0.0001; not shown) and Elephant grass (*P* < 0.0001; not shown) in any production year. In Year 2, there was no difference in yearly yield between Guatemala and Jucao green (*P* = 0.999) or purple (*P* = 0.198).

Crude protein and ME were the only parameters affected concomitantly by two factors, namely species (*P*=.026 and *P*=.014 for CP and ME respectively; Table 23) and harvest height (*P*=.016 and *P*=.001 for CP and ME respectively; Table 23). The NDF content was only affected by harvest height (*P*=.008) while neither species (*P*=.222) or harvest height (*P*=.072) influenced ADF concentration (Table 23). Forages harvested at 1.5 m had lower (*P*=.0167) CP level than when harvested at 0.5 m and Elephant grass had higher (*P*=.0198) CP content than Guatemala (Table 23). The Juncao cultivars did not differ (*P*>.05) from Elephant grass or Guatemala in terms of CP concentration (Table 23). Plots harvested at 0.5 m presented the lowest NDF content with no difference when comparing between 1.0, 1.5 and 2.0 m pre-harvest canopy heights (Table 23). Guatemala grass presented a lower ME content than Elephant grass (*P*=.019) but not different to Juncao green (*P*=.590) and

Juncao Purple (*P*=.088; Table 23). The highest level of ME content was recorded when grasses were harvested at 0.5m of pre-harvest canopy height (Table 23).

Table 23: Nutritional value of Elephant grass, Guatemala, Juncao green and Juncao purple harvested at four different canopy heights over two production years.

	Harvesting height					**Mean**	SEM		***P*-Value**		
	0.5	1.0	1.5	2.0					SP	HH	SPxHH
CP (g kg^{-1} DM)											
Elephant grass	93	85	68	94		85**b**	3.4				
Guatemala	93	76	61	56		71**a**	3.3		0.026	0.016	0.151
Juncao green	89	80	72	71		78**ab**	3.2				
Juncao purple	88	81	75	69		79**ab**	3.2				
Mean	91**b**	80**ab**	69**a**	73**ab**							
NDF (g kg^{-1} DM)											
Elephant grass	650	661	6.9	667		662	79				
Guatemala	664	702	703	678		687	74		0.066	0.008	0.511
Juncao green	644	680	708	692		681	74				
Juncao purple	619	668	683	691		665	74				
Mean	644**a**	678**b**	691**b**	682**b**							
ADF (g kg^{-1} DM)											
Elephant grass	390	390	413	414		402	54				
Guatemala	389	422	418	425		414	54		0.222	0.072	0.635
Juncao green	387	417	415	417		409	51				
Juncao purple	389	407	425	424		411	52				
Mean	389	409	418	420							
ME (MJ kg^{-1} DM)											
Elephant grass	7.6	7.3	6.9	7.4		7.3**b**	0.11				
Guatemala	7.5	6.8	6.4	6.6		6.8**a**	0.11		0.014	0.001	0.777
Juncao green	7.7	7.0	6.6	6.7		7.0**ab**	0.11				
Juncao purple	7.9	7.2	6.9	6.7		7.2**ab**	0.11				
Mean	7.7**b**	7.1**a**	6.7**a**	6.9**a**							

The content of all minerals was affected by fodder species while only phosphorus was affected by harvest height (Table 24). In general, Guatemala grass presented the lowest (*P* < 0.05) concentration of minerals compared to all fodder species assessed (Table 24), with the exception of phosphorus which was not different from Juncao green. The highest concentration of P was observed in Elephant grass while concentration of Ca was highest in Juncao cultivars (Table 24). The concentration of Mg was similar between Juncao cultivars (*P* = 0.963) and Elephant grass (*P* > 0.304) and these were greater (*P* < 0.04) than Guatemala. Juncao purple and Elephant grass had the highest concentration of K followed by Juncao green and Guatemala grass (Table 24).

Table 24: Mineral concentration of Elephant grass, Guatemala, Juncao green and Juncao purple harvested at four different canopy heights over two production years.

	Harvesting height					**Mean**	SEM		***P*-Value**		
	0.5	1.0	1.5	2.0					SP	HH	SPxHH
Ca (g kg^{-1} DM)											
Elephant grass	4.6	3.4	3.3	3.3		3.7**b**	0.26				
Guatemala	2.3	1.9	1.4	1.9		1.9**a**	0.22		<0.0001	0.408	0.341
Juncao green	4.9	4.8	3.9	4.9		4.6**c**	0.21				
Juncao purple	4.6	4.0	4.6	3.7		4.3**c**	0.21				
Mean	4.1	3.5	3.4	3.5							
P (g kg^{-1} DM)											
Elephant grass	6.5	5.6	4.8	6.3		5.8**c**	0.26		<0.0001	<0.0001	0.556
Guatemala	4.8	3.6	2.9	2.5		3.5**a**	0.23				

Juncao green	5.6	4.1	4.0	3.4		4.3**ab**	0.21				
Juncao purple	5.8	5.3	4.0	3.9		4.7**b**	0.21				
Mean	5.7**b**	4.6**ab**	3.9**a**	4.0**a**							
Mg (g kg^{-1} DM)											
Elephant grass	2.5	2.2	2.1	1.9		2.2**b**	0.15		<0.0001	0.354	0.422
Guatemala	2.0	1.8	1.5	1.4		1.7**a**	0.13				
Juncao green	2.5	2.4	2.1	2.8		2.5**b**	0.13				
Juncao purple	3.0	2.4	2.3	2.4		2.5**b**	0.13				
Mean	2.5	2.2	2.0	2.1							
K (g kg^{-1} DM)											
Elephant grass	29	32	35	36		33**bc**	1.69		<0.0001	0.457	0.232
Guatemala	20	23	20	19		20**a**	1.45				
Juncao green	34	29	28	22		29**b**	1.37				
Juncao purple	36	37	34	29		34**c**	1.37				
Mean	30	30	29	27							

7.11 Inventory of local feed resources for livestock feeding in Fiji: availability, chemical composition and value chain perspectives.

The survey on the feed resources used on small ruminant farms in Fiji was conducted in major sheep and goats producing provinces (Bua, Macuata, Ba, and Ra). A total of 248 small ruminant farms consisting of 3 different enterprises (sheep only, goat only and dual farms) were interviewed to collate the information by province and farm enterprise levels. The survey results indicates that most of the small ruminant farms in Fiji are heavily dependent on available pasture-based feeding on farms and they reported to lack knowledge, experience, skills and abilities on animal husbandry and performances in terms of nutritional requirements at critical stages of growth, development and reproduction. The results of this study show that there are considerable differences on the adoption of feeding practices and resources by SR farmers in Fiji. Differences between provinces may reflect opportunities available to SR farmers or local farming practices by provinces. The results suggest that there is a large proportion of farmers grazing Koronivia grass in Northern division while farmers in Western division have a higher adoption of concentrate supplementation such a molasses and mill mix apart from grazing.

Based on the survey results some of the common feed resources and supplementation practices adopted on SR farms during different periods of the year in Fiji are presented in Table 25. The overall percentage of farmers which recorded having unimproved pastures were recorded high amongst all other feed resources in Bua, Ba and Ra provinces except for Macuata province which recorded higher percentage of improved pasture than unimproved pasture (93.7% vs. 88.9%). In Macuata province, the most common improved pasture species recorded was Koronivia grass *(Bracharia humidicola)*. Bua and Macuata province have higher percentage of improved pastures (Koronivia Grass) compared to the Ba and Ra province (64% and 94% vs 15% and 53%). The use of other feed resources such as mineral supplements, concentrates, crop residues & food scraps and feed foliage, fodders or harvested grasses are utilised at higher percentages in Ba and Ra province compared to Bua and Macuata province. The SR farms in Northern division seems largely dependent on pasture-based feeding with very low percentage of farmers reporting any type of supplementation. Unimproved pastures were present on almost all properties surveyed, however the size of area for unimproved pasture in each property is unknown. The adoption of mineral supplementation was found to be more common in Ba and Ra provinces than Bua and Macuata provinces (97 and 57% vs 18 and 6%). Similarly, concentrate feeding was less common in Bua and Macuata provinces compared with the Ba and Ra provinces (5% and 4% vs 40% and 23%). This may be because farms in the Northern division are more remote and have less access to the by-products. Crop residues and food scraps were not commonly used by farmers in Bua, Macuata and Ba province (5%, 2% and 8%) except in Ra province where 33% of farmers utilised the crop residues. A higher percentage of farmers in Ba and Ra provinces reported the usage of foliage, fodder or harvested grasses to supplement SR stock compared to Bua and Macuata provinces (44% and 63% vs 13% and 3%).

Table 25: Feed resources and supplementation practices adopted by sheep and goat farmers in four provinces of Fiji.

Feed resources	Northern Division		Western Division	
	Bua (n=63)	Macuata (n=63)	Ba (n=62)	Ra (n=60)
Unimproved pasture	88.9	88.9	100	98.3
Improved pasture	63.5	93.7	14.5	53.3
Mineral supplements	17.5	6.3	96.8	56.7
Concentrates	4.8	4.8	40.3	23.3
Crop residues and food scraps	4.8	1.6	8.1	33.3
Feed foliage, fodder or harvested grasses	12.7	3.2	43.5	63.3

7.12 Investigating local consumer attitudes, habits, and preferences for sheep meat in Samoa.

From the comparison of consumers' preference for meat quality characteristics lean content ranked 1st for both imported and local sheep meat, 36% and 59%, respectively while, fat content ranked 2nd in both meats (Table 26). Tenderness was a more important characteristic in imported meat (ranked 3rd) than local sheep meat (ranked 4th). Consumers ranked flavour as 4 and 3 in the imported and local meats, respectively. Juiciness was the least on the ranking (5) for both meats. The result stated that price (91%) followed by quality (82%) were the main factors that influenced the purchasing decision of sheep meat by consumers (as shown in Figure 1). Approximately 30% of respondents considered that meat safety, freshness, animal age, and suppliers were important in influencing their decision to purchase sheep meat. Only 2% of the respondents consider animal sex as important. The results of the respondents' ten (10) ideas about ways to help promote and market the local sheep meat in the country. Apart from sharing sheep farmers' experience, there was no significant ($P > 0.05$) gender effect on any of the suggested strategies. More males ($P < 0.05$) were of the view that local sheep meat can be promoted through the sharing of farmers' experience. The majority (46%) suggested awareness programs by the Ministries of Agriculture and Health about the benefits of local over imported sheep meat.

Table 26: Comparison of consumers' preferences for meat quality characteristics of imported and locally produced sheep meat (% and ranks).

Characteristic	Imported sheep		Local meat	
	Respondents (%)	Rank	Respondents (%)	Rank
Lean content	36	1	59	1
Fat content	28	2	21	2
Flavour	18	3	5	4
Tenderness	14	4	15	3
Juiciness	4	5	0	5
Total	**100**		**100**	

The study found that leanness is the most preferable characteristic by consumers for both imported and locally produced sheep meat. Price was the main factor that influenced consumers' purchasing decisions. Most consumers preferred to shop at the supermarket due to convenience, trust in the meat quality, and price advantage (Figure 24). Supermarkets are likely to be key partners for developing and promoting local sheep production in Samoa. The outcome of this study can benefit policymakers, investors, and all sheep chain actors for strategies to improve the local sheep sector in Samoa. Production and marketing need to be aligned with consumers' preferences, and supply of safe, healthy, high-quality meat that is affordable for consumers and profitable for producers.

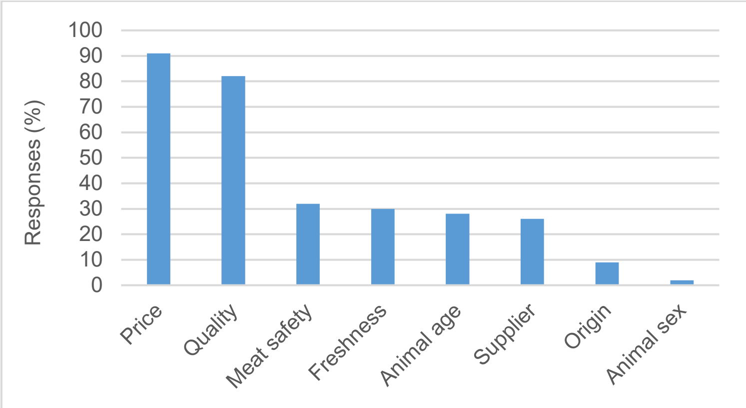

Figure 24: The relative importance of factors influencing consumer purchasing decision for sheep meat.

7.13 Gross margin analysis of small ruminant production in Fiji

A budget for a representative goat farm was developed using the CoP/GM calculator. It is termed "representative" because it is assumed to possess the farm characteristics, production parameters and a set of farming practices that were considered either as the benchmarks for the industry or the recommended or best-fit practices that suit the local conditions. Production parameters and assumptions, and the resulting changes in flock structure are presented in (Annex 11.4) As shown, the goat farm is assumed to have 50 does and 2 bucks with a kidding rate of 150%, and at the end of the production cycle there are 64 kids that have survived; they all will be sold, except 8 females that are retained as replacements. The 64 kids weigh 1,763 kg in total in live weight. The remaining 24 females, along with 32 males and 7 culled females are sold, generating a total of FJ$16,849 in revenue.

Financial performance of the representative goat farm is presented in the summary budget (Annex 11.4). In particular, it indicates that running a goat farm with 50 does and 2 bucks requires an initial investment of FJ$58,861, which includes the purchase of breeding stock, the lease of 10 acres of grazing land (assuming a carrying capacity of 5 does per acre), the establishment of 1 acre of improved pasture, and the construction of shed and fences to support a semi-intensive grazing system, as well as tractor/truck, watering facilities and other farming equipment. These costs are annualised according to the percentages at which they are used by the goat enterprise, salvage value, and years of service. The resulting figure is FJ$5,167 per year, which is composed of land lease, depreciation, taxes, interest payments and insurance. Total variable cost (FJ$13,488) consists of expenses on feeds, vet medicine and services, repairs and maintenance of shed, fences, and machinery, and the running cost of the machinery (tractor, truck, pumps, etc), and the labour costs of hired casual workers, as well as the opportunity cost of family labour valued at FJ$3,285 = FJ$3/hour × 3 hours/day × 365 days.

GM for the representative goat farm is FJ$3,360/year, after deducting TVC from TR. This is a favourable result in three significant ways. Firstly, a positive GM means not only does the goat farm generate enough revenue to compensate for the use of family labour and own capital, but also has extra to recoup some of the initial investment costs of FJ$58,861, although it would take 18 years to recoup it all. Secondly, variable CoP and total CoP are FJ$8/kg and FJ$11/kg, respectively, which is also good news because they represent the breakeven prices that are necessary to cover the cost of production, and they are close to or lower than the prevailing market price of FJ$8-12/kg. Thirdly, both GM and CoP were generated based on conservative estimates, ie TR is estimated on the low side while costs are on the high side. Based on the on-farm and market research conducted, some issues and opportunities have been identified. In this section, those results are summarised and implications for developing a competitive and profitable goat/sheet industry in Fiji are presented. Based on the on-farm and market research conducted, some issues and opportunities have been identified. In this section, those results are summarised and implications for developing a competitive and profitable goat/sheet industry in Fiji are presented.

Several challenges facing the SR farmers were identified in this study. Firstly, production has increasingly been affected by weather/climate change: more frequent droughts and floods, as well as cyclones. The cyclone in 2019 was particularly severe; many farms were badly damaged and in some areas 30-50% of SR were lost. Three years on, some farmers were still trying to recover and rebuild. Second, theft and dog attacks on goats and sheep are an enormous issue for the SR sector in Fiji as they cause large numbers of animal deaths and losses. Because of the threat of dog attacks by day and night, farmers are always on the lookout, often they stay watching while the animals are grazing, contributing to time cost and mental stress. Animals lost to dog attacks could be as high as 30%. No amount of productivity gain could possibly make up such heavy losses. Third, unavailability, poor quality and high costs of major farm inputs, including drenches and other vet medicines, feed ingredients, and fencing materials. The quality of fencing materials appears to be a major concern as they last only 2-3 years, exacerbating the threats from dog attacks and the high cost of repairs. Fourth, lack of land for expansion or for feed supply; and fifth, deaths in the wet season. Interestingly, there was no mentioning of marketing being an issue. It seems demand is high and prices are good. Severe supply shortages, on the other hand, was the major issue identified by marketers of the formal market chain.

During the market survey conducted in October 2022, it was found that sheep meat imports (lamb chops and others) have a constant presence at the supermarkets and butcher shops, but locally produced goat or sheep meat was very hard to find. Several butchers and supermarkets interviewed were unable to source any goats in recent months. For those who could, sales volumes had been reduced (from 4-5 goats/week to 2-3 goats/week) and at significantly higher prices (increased from FJ$6-7/kg to FJ$9-10/kg live weight). In fact, 80% of the supermarkets and butchers visited have not been selling goat meat since 6 months ago. Most international hotels/restaurants visited either did not have goat dishes on the menu, or they were unavailable.

Gross margin analysis is a useful tool for assessing financial performance of small ruminant farms in Fiji, as well as for demonstrating the impact on cost of production and gross margin of a change in production parameters or farming practices. The results show that in most scenarios, gross margins for SR farming were positive even after accounting for opportunity costs of family labour and capital. The main reason for the positive outcome was the way small ruminants were marketed – live animals are sold at high prices directly to households at the farm gate. However, locally produced sheep or goat meat may not be competitive with imports at the formal market in terms of price, quality and consistency in supply given current value chain configuration. The conclusion is that to compete at the formal market, a vale chain approach in needed from improving access to key farm inputs to improving marketing infrastructure, to building consumer confidence.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project has supported and funded initiatives to embed scientific knowledge into the practices adopted by farmers as well as Ministry of Agriculture. Two examples of the successful application of these were the development of the grazing management ruler and FAMACHA card. A pasture ruler for Koronivia grass (*Urochloa humidicola)* was developed based on the scientific literature available. The ruler is a practical tool that have been made available for farmers to improve their grazing management practices (Figure 25). In addition, we have also developed an "anaemia guide" translated into hindi and iTaukei which has been used by MoA staff as well as farmers as a diagnose support during the drenching decision. We believe that the introduction and dissemination of technical concepts will positively influence not only the ministry staff but also farmers and industry stakeholders.

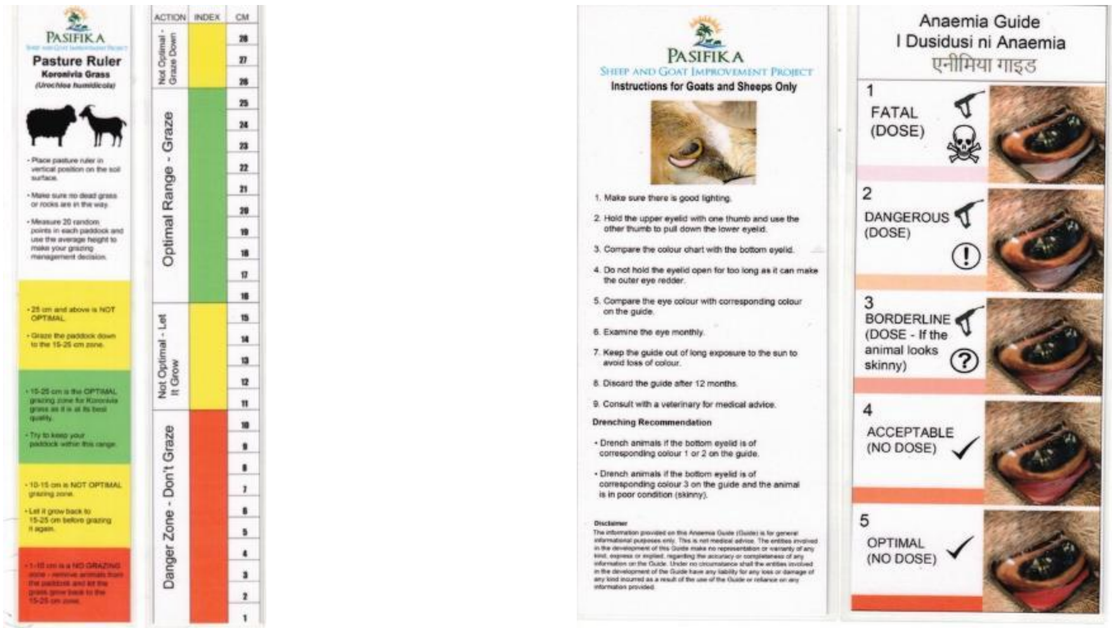

Figure 25: Front and back side of the Koronivia pasture ruler and front and back side of the anaemia guide for sheep and goats.

8.2 Capacity impacts – now and in 5 years

Probably one of the most significant impacts of this project was on the capacity building of collaborators and partners. We have conducted several training programs (Table 27) which were tailored and adapted throughout time accordantly to the needs presented. In addition, all four project officers from Fiji have already been absorbed and hired either directly by MOA of by similar research projects. In Samoa, one project officer was recently hired by USP to work on a similar research project. One of the project officers in Fiji was hired to work at the Koronivia Veterinary Laboratory responsible for processing the parasitology samples. The project has also funded the implementation of three parasitology laboratories by providing equipment (i.e. incubators, microscopes, glassware and consumables) and training. Two of these labs were set up in Fiji (Labasa and Lautoka) and one in Samoa (Vaea Research Station). In Fiji, the location of these new labs has improved in a significant way the capability of MOA to process parasitology samples. Approximately

95% of the small ruminant population is in the Western and Northern Divisions and previously the only lab (Koronivia Vet. Lab.) able to process parasitology samples was in Suva in the Central Division.

During the period of the project, we have observed a significant change in knowledge and management skills within the Ministries staffs. Before the initiation of PSGIP both ministry teams had no previous experience managing international projects nor conducting research activities. Currently the MoA is involved with two new ACIAR projects apart of other external funding bodies which demonstrate an upskilling by the whole team (including legal, finance and other administrative departments) to be able to manage and administrate all these cooperation activities. It was also noticeable that many concepts (e.g. from gender equality to SR husbandry practices) that were initially discussed as foreigner by the team ended up being absorbed and embedded into the ministry practice and culture. The teams have constantly demonstrated eager to growth and take advantage of opportunities (e.g. ACIAR projects) to upskill staff and improve the ministry services offered to farmers. More importantly, this has been supported by higher ministry officials which greatly facilitate the implementation of activities and actions.

Table 27: List of formal trainings conducted during the PSGIP.

Training	Responsible	Participants	Period
Training: Digital data collection	Jenny Hanks & David McGill	Ronil Prasad, Donna Aiulu and Tiago Silva	October 2019
Workshop: Research methodologies training	Fran Cowley & Tiago Silva	MOA, MAF, FNU and USP – Total of 44 participants	November 2019
Training: Pasture management	Tiago Silva	Online training – total of 26 MAF, MOA and project officers	October 2021
Training: Cost of production for small ruminant properties	David Falepau and Michael Campbell	MOA and FNU – Online 14 participants	December 2021
Training: Grazing management: Science into practice	Tiago Silva	MoA and MAF – Total of 11 participants	December 2021
ANZCCART – ComPass Animal Welfare Training	The University of Adelaide	MoA, MAF, HRD students and Project officers – Total of 12 participants	March 2022
Training: Exploring GESI Workshop for Ministry of Agriculture Extension Officers.	Anna Cowley & Flavia Ciribello	MoA and PSGIP officers – Total of 9 participants	March 2022
Training: Economics of sheep and goat production	Christie Chang	MoA, PSGIP officers and local farmers – Total of 36 participants	June 2022
Specialization course: Everyday excel	University of Colorado	Toya Areta & Zac Sua'a	June 2022
Training: Small ruminant production husbandry practices	Tiago Silva	Fijian farmers – Total of 93 sheep and goat farmers.	September 2022
Training: Faecal egg count and larval differentiation methodologies	Gurdeep Kour	MoA, MAF and PSGIP officers – Total of 37 participants	August & November 2022
Training: Sheep production in Samoa	Tiago Silva	Samoan farmers – 46 in total from Upolu and Savai'i	November 2022
Training: Faecal egg count, larval differentiation and total worm count	Gurdeep Kour & Tim Elliot	MoA, MAF and PSGIP officers –Total of 15 participants	March 2023
Workshop: Gross margin analysis for sheep and goat farms	Christie Chang	3 sessions for MoA extension/research staff, FNU agribusiness staff and students and Project officers. Total of participants: 59	May 2023
Workshop: Farm economics for small ruminant farms	Christie Chang	MoA and PSGIP project officers (Fiji & Samoa) – Total of 21 participants	Augst 2023
Financial literacy training in Samoa	SBH & Flavia Ciribello & Georgina Bonin	Total of 24 participants in Upolu and Savai'i.	November 2023

We have also requested anonymous feedback from our project officers and the response was overwhelmingly positive. Here are some sections of the responses provided:

"…I'm forever blessed to be employed and working with the project is the best thing that has happened to me. I'm grateful to people that I have worked with and have worked with along the way and learning to be confident in my work especially with SR production."

"So far in this project I have improved on most levels developing skills in data entry using Microsoft Excel, sheep handling, survey skills and most importantly the use of the Commcare app. The best thing about this project is seeing the improvement in production, such as witnessing a good amount of newborns for each of these farms and the build-up in the farmers' interests towards the project."

"…the best part of being this project is to come across experts who guide us in appropriate way in enabling the project to be a reliable and successive one. Learning from them and supporting them is of great importance."

"The things which I have learned within this project is humane way of handling animals during the drenching, ear tagging or weighing the animals. I had also learned the different types drench as in the dosage rate given on the different body weight. While being part of the project I had also acquired knowledge on how to detect anemia in small ruminants and how to do post mortem by attending the Sheep Extension Training. I had also learned about pastures by attending the Pasture Management Training."

"I grew up on a farm, surrounded by the very same animals that I now work with, as such I am very thankful and inspired by this project and the benefits it poses for farmers all over my country and am proud to be a part of this revolutionary program."

Higher research degrees (HRDs) completed through PSGIP

There has been a hiatus of small ruminant research in Fiji and Samoa over the last decades and more recently there were very few ministry staff with research qualifications specifically in the area of small ruminant production. So, the students that were trained and graduated within this project represent a new cohort of researchers which will be able to contribute to the local industry.

- Ronil Prasad - Inventory of Local Feed Resources for Small Ruminant Feeding in Fiji: Availability, Chemical composition and Vale Chain Perspectives; MSc Degree at The University of South Pacific – Completed.
- Gulista Dean - Consumer's perception and willingness to consume goat milk and milk products in Viti Levu, Fiji; MSc Degree at The University of South Pacific – Completed.
- Tusiata Lemuelu - Investigating local consumer attitudes, habits, and preferences for sheep meat in Samoa; MSc Degree at The University of South Pacific – Completed.
- Gurdeep Kour - Understanding the impact of and solutions to inefficient worm control in tropical small ruminant production system - a Fiji case study; PhD at The University of New England – In progress

8.3 Community impacts – now and in 5 years

Although it may be difficult to dissociate the effect of this project to other initiatives taken place, we can safely attest that a significant change in mindset and behaviour was noticed among participating staff from Fijian MoA and farmers. The same cannot be attested for MAF in Samoa as well as local farmers.

8.3.1 Economic impacts

Despite not being able to measure direct economic impacts giving the time restrictions on this project. The PSGIP has identified and recommended direct measures based on the results obtained by the several research activities conduced. In addition, the project helped to clarify many existent misleading pre-conceptions in relation to: the impact of worms on sheep and goat production in Fiji and Samoa, the level of efficacy for the current anthelmintics available, level of reproductive performance, proportion of animal losses, utilisation of small ruminant animals by farmers, nutritional quality of Juncao grass varieties green and purple and benefits of supplementation before and after weaning.

If, adopted the recommendations provided have the potential to significantly improve productivity and economic returns potentially above the benchmark values (i.e. 75^{th} and 25^{th} percentiles) suggested in this document. On a sequence of priority these are: Reduce proportion of missing animals (dog predation and thefts), improve conception rates (improved nutrition and culling selection) and establishing improved pasture area for weaners. Our estimates shows that even with this high level of losses, sheep and goat business are an important source of income for farmers which demonstrate the rentability that could be achieved if external sources are minimized, and animal productivity is improved.

8.3.2 Social impacts

Probably the most evident social impacts we observed during this project was in relation to the gender roles on-farms as well as within the Ministry as institution. We have noticed that a considerable proportion of the women included on the on-farm monitoring program to be more involved and taking active roles within time. For instance, it was clear that women would take the responsibility for recording the information (e.g. births, sales, expenses etc..) on the project booklet and in general, the recording was much more organised than when men would take this role. In doing that, they became more participative during farm visits, discussing the results and interested in collaborating with farm activities. It's also likely that the gender mixed composition of the project officers' teams has helped to develop these situations. It was noticeable to see some of these topics (e.g. gender inclusion) and concerns being more common on the daily conversations and interactions between ministry staff and farmers.

One direct example of this change in mindset was that in March 2024 was the first time that the Fijian Ministry of Agriculture awarded preeminent women working in the Fijian agriculture sector. This is an important and significant message that shows the institutional mindset in relation to efforts to decrease gender disparities. Obviously, as we previously mentioned, this cannot be directly associated only to this project but to a group of initiatives that have strengthened the importance of gender equality over the last years and this project was responsible for some of them.

8.3.3 Environmental impacts

We initially had one activity in this project (1.8) which was within Objective 1 to monitor the environmental impact caused by small ruminant systems. This activity however was later decided to be discontinued given the competing priorities existent after the lift of COVID restrictions.

8.4 Communication and dissemination activities

Throughout the project our main communication channel for dissemination of activities was through the project social media channels (i.e. Facebook & Instagram) which accumulated a total of 1,087 followers. Many of our posts have reached over 20 shares being visualised for over 8,500 people (each post) where the majority women (51.3%) in the 25-34 years age bracket. The locations where most access were made: Fiji (36.1%), Samoa (23.8%), Australia (10.1%) and New Zealand (8.3%).

This project in collaboration with Fijian Ministry of Agriculture funded the development of National Certificate Level 2 course in Small Ruminant Production in Fiji. The course will be built structured utilizing new knowledge developed during the PSGIP as well as previous research. It will be offered to farmers and MOA will fund half of the tuition fees of participants in a similar model to what was developed for the dairy industry (MOA 2023). The implementation of this course will ensure that the knowledge and findings obtained through this project will benefit a significant number of farmers on the years to come.

Articles in newspapers/magazine/blogs

- https://www.aciar.gov.au/media-search/blogs/sheep-and-goats-focus-livestock-productivity-challenges
- https://www.crawfordfund.org/news/improving-animal-production-in-fiji/
- Fiji Times – Commercial production of sheep and goats.
- https://www.spc.int/updates/blog/a-conversation-with/2023/08/lrd-research-in-focus-meet-gender-and-value-chains-advisor?fbclid=IwZXh0bgNhZW0CMTAAAR2ycHnzS7TsQ_6RPBAne_pNHhPmbrLkrQWNk0uCCi0BMDzqkDP8N0CA4n8_aem_eUnQI_33cM2Cz5HodUY-Sg
- Presentation during Fiji Agricultural show 2023

9 Conclusions based on research questions and recommendations

In this section we will attempt to directly address the research questions raised during the proposal of this project by concatenating information generated throughout the project by the different research activities.

9.1 Research questions

9.1.1 What is the current variation in production systems, feed resources and young animal losses in Fijian and Samoan SR farms?

While it seems reasonable to say that there is not as much variation in terms of types or characteristics of production systems in the sense that most farms (within country) have very similar infrastructure, work routine, technology applied and feed resources available (e.g. pasture and supplementation). The same cannot be said in terms of production performance for each of these systems. The details of the overall characteristics of farms in Samoa and Fiji are described in detail in Section 7.1 and 7.11 while productive parameters are presented in Section 7.12. In these sections we have highlighted significant differences between the top 75th and bottom 25th percentile farms in relation to growth performance, reproductive rates, losses (i.e. mortality and missing rate), monthly sales, gross and net monthly income. The benchmark values obtained (75th or 25th percentile) are a valuable resource to be utilised as a reference for farmers and police makers in the future in order to compare their own production systems or help to plan polices for this sector.

9.1.2 What is the scale, causes, and solutions to young animal losses in sheep and goat flocks?

The most significant source of losses in Fijian farms derived from “missing animals” while in Samoa is by mortality rates. It’s likely that a portion of missing animals in Fiji to had been dead animals which were not properly recorded. In any case, the data still suggests that missing animals are the most significant source of losses and probably caused by dog predation and thefts. The median mortality values recorded for farms in Samoa are within the range of values observed in the literature for similar production systems and climatic conditions suggesting overall restricted opportunity for improvement. In Fiji, missing animals represent a significant opportunity for improvement but one that needs to be tackled with the support of many other government and NGO’s bodies since it affects many other sectors of Fijian society.

9.1.3 How can better flock husbandry and management improve the turn-off of weaners per breeding female?

There are three husbandry practices that should be recommended in both countries that can improve turn-off, and these are: establishment of a joining season, culling females which fail to deliver an offspring and weaning of lambs and kids. We have observed that an average of 20 to 38% of the reproductive females are currently not giving birth within a year. In addition, we have measured that in average only 4% of the reproductive females are sold within a year. These parameters show a pattern which is very common among less efficient farmers where there is an aim for increasing flock and herd size and because of that there is not a establish strategy for culling dams which are usually kept in their mobs until death or disappearance. This intuitive but misleading strategy leads to two negative consequences:

1. Females with lower reproductive performance are kept in the farm eventually providing an offspring which will also have a lower genetic merit leading to a decrease in reproductive efficiency of the mob with time.

2. The potential income that could be generated by selling “empty” females is lost by death of if the animal goes missing.

In order to establish these practices, the minimum investment necessary would be to have at least one separate paddock where weaners can be moved to separate from dams. The other practices do not necessarily need any monetary investment and complement each other. For instance: once a mating season is established is much easier for farmers to identify females which have not given birth, since all births will be happening at the same time, and therefore sell these animals. Obviously, the farmers would be able to achieve the same objective by data recording but it’s not a practice to be implemented easily.

When thinking about concentrate supplementation in order to accelerate weight gain, we have observed that creep-feeding supplementation seems to provide a much better return on investment than supplementing weaners. In our trials we have opted to utilised well known imported ingredients (e.g. wheat and soybean meal) which despite being more expensive provide reliability which in many situations cannot be offered by local byproducts. Even with these considerations, creep-feeding showed to provide a positive return.

9.1.4 How can home-grown and locally-sourced feed resources be integrated into Fijian and Samoa production systems and livelihood strategies to reduce feed gaps and increase breeding efficiency and weaner turn-off?

For all farms we interviewed and included on the on-farm monitoring program, grazing was the main feeding method despite the sporadic utilisation of concentrate (e.g. mill mix, copra meal and brewers grain) and/or fodder supplementation (e.g. Juncao and Vaivai). However, grazing areas are usually marginal land which were not utilised for cropping and have not been planted with any specific pasture species. They are areas where previously introduced pasture species (e.g. guinea grass, setaria, koronivia grass and para grass) or native (e.g. baitiki blue and nadi blue) grows mixed with a heavy presence of weeds. These grazing paddocks could be better described as an opportunistic utilisation rather than a planned area devote for grazing. Across Fiji and Samoa is very rare to find paddocks or fodder growing areas that were planted and/or managed aiming feeding ruminants. We have demonstrated in Section 7.10 that fodder forages have the potential to produce high biomass with quality necessary to supplement small ruminant production during the dry season. However, is much more important for these farms to have designated grazing paddocks planted with improved pastures and managed free of weeds before start thinking about supplementation options for the dry season. The grazing paddocks should be the foundation stone where these systems are built upon and currently there is very little importance and prioritization of this component. However, in Fiji and Samoa farmers face a significant limitation when establishing grazing areas given the lack of availability of pasture seeds as well as on-farm machinery.

In situations where there is deficit of pasture availability during the dry season, the utilisation of Juncao green or purple showed to be a good alternative. We have estimated that only 1 ha of these varieties would be necessary to feed approximately 155 to 219 small ruminants (or 16 to 23 head of cattle) over 122 days (dry season). The project has produced a leaflet utilizing the information generated through Section 7.10 informing on planting, harvesting and utilisation of these fodder grasses (Annex 11.3).

9.1.5 To what extent is SR production in Fiji and Samoa constrained by gastrointestinal parasitism?

Based on the results discussed in Sections 7.1, 7.4, 7.6 and 7.1 we can conclude that gastrointestinal nematodes in Fiji and Samoa are currently less restrictive to small ruminant production than other factors (e.g. nutrition, mob structure, cull and replace females and establishing a joining period). We have observed during baseline survey that worm burden was over 1,000 epg in some properties in Fiji which is high and imposes a limitation to productivity. However, we have also identified that anthelmintics currently commercialised in the country (levamisole), despite presenting some level of resistance, still promoting a significant reduction in FEC (91.6%). In Samoa, the constrains caused by gastrointestinal nematodes seems to be even less significant given the low levels of worm burden measured during the baseline survey as well as during the on-farm monitoring program. In addition, we have measured the productive performance of ewes and does which were submitted to a suppressive treatment for gastrointestinal nematodes over at least one year (Section 7.1). The results showed females “free of worms” had a statistically significant higher liveweight, body condition score and FAMACHA when compared to the control groups. However, these differences were biologically insignificant and did not translate into an improvement in reproductive performance or growth performance of their offspring.

9.1.6 What is the scale and severity of anthelmintic resistance in semi-commercial and smallholder herds, and which practices are promoting anthelminthic resistance?

The severity of anthelmintic resistance in Fijian small ruminant farms is much lower than we previously hypothesised. However, it should be clarified that by definition albendazole (65.2%), levamisole (91.6%) and albendazole plus levamisole (94.3%) should be classified by existing resistance given the limit threshold of 95% for faecal egg count reduction test. However, apart of albendazole, the utilisation of any of these drugs would provide significant reduction in worm burden contamination. We have initially suspected that anthelmintic resistance would be a significant problem in Fiji based on the following reasons:

1. Cowley *et al.* (2019) when conducting a survey across several farms in Fiji measured worm burden levels of >1,400 epg and >2,400 epg in sheep and goat’s farms respectively. In addition, these farmers reported to be drenching their animals every at regular intervals in an average of every 1.6 months (~48 days).
2. During the baseline survey of this project (Section 7.1), we observed a variation from approximately 375 epg during the dry and 1,250 during the wet season while farmers reported to drench in a fixed interval of 35 days.
3. The currently commercialised drugs by Ministry of Agriculture in Fiji – Levamisole – have been available for farmers for over 30 years.

Taken together, these facts led us to believe that high gastro-intestinal contamination levels observed on Fiji farms was being caused by inefficacy of the commercialised drugs. During this project we reached the following conclusions:

1. There is in fact a lower than 95% efficacy in faecal egg count reduction for levamisole in Fijian small ruminant farms but the reason for the occasional high contaminations levels observed is not being caused by the reduced efficiency but from incorrectly and infrequent administration of drenches instead of an overutilisation as previously speculated.
2. Farmers have frequently overestimated their yearly drench utilisation in different surveys. The reported frequencies provided by farmers do not match their measured expenditure during the on-farm monitoring program. It’s likely that farmers reported in the survey what they believe to be the “right answer” since drenching all animals monthly has been a recommendation promoted by the Ministry of Agriculture over many years.
3. Despite the existing low level of resistance for levamisole, its recommended that this drug not to be used alone but in combination with other drugs (e.g. macrocyclic lactone group). The continuous utilisation of levamisole alone can lead to an increase in resistance level in the future.

9.1.7 How can parasite management be improved so as to control the impact of worms, and reduce the cost of production without promoting drench resistance?

From a governmental point of view the Samoan Ministry of Agriculture is currently being very effective in providing to farmers combination drenched which have smaller chances of developing resistance. The result of this action can be noticed by the overall low levels of GIN burdens observed on-farms. In Fiji, would be recommended for the Ministry of Agriculture to adopt a combination drug in substitution of levamisole alone. One possible option would be the formulations containing levamisole and abamectin. The adoption of this combination would greatly reduce the chances of resistance development. In addition, we have suggested that one of the possible reasons for the suspicious around low efficacy for levamisole to be caused by incorrect administration of drenches. We have observed that majority of farmers would never weigh their animals before providing the drugs which could be a significant source of dosage error.

From a farmer management perspective, we have suggested a series of steps that farmers can follow in order to improve their productivity and management in Section 9.2.3. The most important concept (in relation to worm control) is to slowly implement a sectorization of their flocks/herds by establishing a joining season and start weaning kids/lambs when they reach approximately 3 months old. This sectorization would allow farmers to prioritize worm control of specific groups throughout the year removing the necessity of drenching all animals at once. For instance, pre-parturient ewes and weaners which are the groups identified to have higher susceptibility to gastrointestinal nematode infection.

9.1.8 What are the impacts of different SR production systems and market destinations on rural livelihoods and the environment?

While some initiatives were developed in Fiji by MoA in order to promote farms to specialize in backgrounding and fattening. The majority of farms, in Fiji and Samoa have a “complete cycle” operation where most flock/herds have breeding, backgrounding and fattening. However, in most cases there is no change in management practices between these phases and very little input utilised. Currently, the main market destination of these farms is farmgate sales given the difficulties (e.g. distance to abattoir) and very little incentives (e.g. very high prices as farmgate sales) for farmers to slaughter their animals in an abattoir (FMIB located in Vuda and Suva) in Fiji. Based on the data obtained from the agriculture census conducted in Fiji in 2019, Dyer et al. (LS/2018/183) suggested that the proportion of sheep/goats going into abattoirs (formal market) was of approximately 20% and home consumption 27% of all turned off animals. This data was originated from a description provided by farmers of their recollection of sales, home consumption and slaughters over the last year and are very different to the values obtained in our records. We have measured that in Fiji and Samoa the proportion of animals commercialised, home consumed and gifted were 80 – 90%, 12.6 – 7.5% and 2.3 - 9.7%, respectively. In addition, for all the turn-off transactions recorded on-farm (n = 709) none of them was through the formal market (e.g. abattoir). This data suggests that farmers in Fiji and Samoa raise sheep and goats for the main reason of financial profit. This pattern is consistent across different farm sizes and locations. We have noticed throughout this project in many situations that information provided by farmers in one-of surveys can be very misleading and different result are obtained if the parameters are measured.

In Section 7.4.7, we estimated the net monthly income obtained through sheep and goat business without accounting for other sources of income generated by other farm activities or external employment. However, across the baseline survey we have identified that most (68.3 to 62%) farmers in Fiji have a weekly household income of 0 to 250 FJ$/week, and in Samoa despite being a bit more disperse, the majority of respondents (29.6 to 38.4%) were also in the 0 to 250 WST$/week. We have estimated that in Fiji the mean net income to be of approximately FJ$499/month with suggests that for most of these families sheep and goat production collaborate with **half of their household income**. In Samoa, as we previously discussed, the labour costs have been attributed only to sheep production which provides a distorted figure of costs since that labour cost was being shared across many other activities. When removing the labour and fuel costs from the Samoan farm estimates we observe that even then the average net monthly income is only WST$37.5 or approximately 7.5% of their monthly income.

9.1.9 What are the decision-making considerations by men and women farmers (e.g. production system, social and whole-farm activities and income sources) which affect the adoption of on-farm technologies?

It seems that there are greater differences in behaviour in relation to adoption of technology when comparing farmers across different locations than different genders. However, some gender differences were observed and discussed in Section 7.2. A noticeable difference in on-farm technology adoption can be observed when analysing the results of Section 7.11 and 7.1. For instance, fodder supplementation, concentrate supplementation and weaning were more common in the main island's (Western Division and Upolu) when compared to the outer islands (Northern Division and Savai'i). On the other hand, castration was more common in Samoa as a whole (both islands) than in Fiji. While the adoption of some technologies seems to be linked with accessibility to resources (e.g. supplements) others seems to be related to cultural practices (e.g. castration) and farmers behaviour. Overall, famers in Fiji often externalised more strongly their aspirations of improving their production systems and adopting technologies to improve it than in Samoa. On the other hand, Fijian farmers were also more dependent on the financial resources provided by small ruminants and usually had more years of farming experience which made them conservatives in terms of changing their "usual practices". Samoan sheep farmers are in general better educated and of a higher social-economic group which stills utilizes a lot of the food resources produced on-farm but not necessarily depend upon this production to survive as the great majority of them and their families have other sources of income.

9.2 Recommendations

Based on the results discussed above we have tried to elaborate a list of recommendations for farmers and another one to the Ministries of Agriculture for each participating country.

9.2.1 Fijian Ministry of Agriculture and Waterways (MoA)

1. By far the biggest cause of losses faced by small ruminant farmers is by "missing animals" which cannot be classified given the unknown and represents in average 9.3 to 27.8% of reproductive females within a year with individual farms recording values as high as 35.5%. It's likely that a portion of this missing animals are non-reported on-farm deaths but the majority of these most likely caused by a combination of thefts and dog-attacks. These two problems are well known to the community and should be tackled in collaboration with other sectors of the government since they also affect other aspects of society. It's not our goal here to suggest how these problems can be solved but to shed light to the size of the problem since from our knowledge this is the first time that the magnitude of this losses was recorded and not estimated. We believe that this information is an important tool that stakeholders and government officials can utilize when discussing and planning alternatives for these problems.

2. The current commercialised drug at the veterinary clinics (i.e. levamisole) of MoA presented an average efficacy of 91.6%. Despite this level of efficacy was higher than previously expected it is still below the recommended threshold (95%),

therefore it's not recommended for this drug to continue to be commercialised in its single formulation but to opt for a formulation which combine this drug with another with high efficacy (e.g. macrocyclic lactones group). Livestock-specific guidelines and policies need to be developed for the current veterinary anthelmintics that are being used in Fiji. The guidelines should be transferred to farmers by an educational program on best practices on drenching usage. Private organisations which employ veterinarians can supply veterinary anthelminthics to their own clients (equivalent to S4 drug regulations in Australia) but can't retail such medicines. However, there are few private veterinarians in Fiji, mostly working in companion animal medicine, and so in practice, the Government, through the MOA is the sole provider of large animal veterinary medicines. Based on the discussion raised in this document it seems advantageous from a worm control perspective if private organizations to be allowed to retail such drugs but also to be able to retail a greater range of veterinary anthelmintic products. However, it's important that the facilitation of access to purchase these drugs to be linked with a specific usage guideline and extension program to inform farmer about the potential risks and benefits.

3. From all factors investigated throughout the trials conducted in this project the most effective way to improve performance was through nutrition improvements which was more significant than genetic improvement (Section 7.9) and control of gastrointestinal nematode (Section 7.1). This is an important observation because quite often investments in genetics alone are made with the hope of a significant improvement in productivity and quite often these expectations are not met due to the lack of an environment that allows the higher genetic merit to be expressed. Fiji has an ideal environment (e.g. rainfall, temperature and photoperiod) for development of tropical pastures and this advantage should be explored as the cheapest source of nutrition for ruminants. However, while achieving high yields per area with tropical pastures is relatively easy, achieving high yield with high nutritional value is highly dependent on grazing management. Is of foremost importance for the country to implement a research and extension program focused on improving grazing areas by introducing selected pasture cultivars, enhance soil fertility, controlling weed infestation and promoting grazing management to increase output per area (i.e. meat or milk per hectare) for ruminants in general. Tropical pastures are and always will be the foundation stone of any ruminant production system in Fiji and developing this area of research should be one of the priorities of the agriculture sector. In addition, improving grazing management have a direct link to decreasing surface erosion (water run-off) which causes directly harm to waterways and corals. In Australia, it has been identified that approximately 45% of sediment run-off are originated from surface erosion and 39% from streambank which can be reduced by improving management of catchment areas. The Australian Government have implemented several initiatives (e.g. grants programs, Grazing BMP, regulatory mechanisms and industry targets) to improve farm management and therefore reduce the impact on the Great Barrier reef (Bartley *et al.* 2017). In Fiji, tourism contributes with approximately 40% of the GDP and the strength of this industry is directly linked to the ocean environment and coral reefs biodiversity. Is therefore, of foremost importance to develop a research/extension program aiming to improve grazing management, increase animal productivity and reduce the impact on the coral reefs.

9.2.2 Samoan Ministry of Agriculture and Fisheries (MAF)

1. Farmers in Samoa have relatively little experience in growing sheep, and this can be assessed by the average years of experience in the business as well as the suggestion made by most farmers in Savai'i which lack of information was the most restrictive factor for their business. In addition, a very high proportion (40 and 23%) of farmers reported to have completed undergraduate degree. This represents a

valuable opportunity for the ministry to foster and disseminate knowledge in order to embed "best practices" for these new farmers. The higher education levels already achieved by Samoan farmers and relatively low experience is likely to contribute to a greater uptake of Ministry recommendations. Extension programs and trainings to provide famers the knowhow of basic management practices would be very valuable to stimulate a sustainable grow for this industry.

2. The size of farms in Samoa (2.6 to 1.7ha) are already very small when considering the average flock sizes (15.4 and 18.1 head). It will be necessary for farmers to establish improved grazing areas in order to accommodate business growth. A research and extension program training farmers in establishing and managing improved pasture will be necessary.
3. Samoa accommodates the Agricultural campus of the University of South Pacific and would be very beneficial for the Ministry, farmers and students if a more intense partnership and collaboration for internships could be established. This could be a way to better capacitate the new graduates with field experience working on research trials at Vaea Research Station or helping extension officers during their visits.

9.2.3 Farmers – Fiji & Samoa

1. Keep track of your animals and make sure your fences are well maintained. If you have cases of dog attacks in your area, try to maintain the animals closed in the animal house at night.
2. Aim to plant at least one paddock of improved pastures where lambs/kids can graze during weaning separate from their dams. This paddock needs to be fenced in order to avoid offspring to rejoin their dams.
3. Start weaning lambs and kids when they reach approximately 3 months. Would be preferable to feed them some source of protein supplementation (e.g. leucaena or mill mix) when doing that as well as drenching all lambs and kids. Weaners are the most susceptible class to infections by gastrointestinal nematodes so special attention should be given over the next 2-3 months in order to decrease losses.
4. Implement a joining season – This can be done by starting with a 6-month period and reducing to 60 (~ 3 oestrous cycles for sheep and goats) days in 4 years. Given that naturally the concentration of births is already concentrated in Jul and Aug, joining can be done in Feb – Mar. In this sense the joining season would be: Year 1: Dec to May; Year 2: Jan to Apr; Year 3: Jan to Mar; Year 4: Feb to Mar.
5. Sell a minimum of 15% of the mature females every year (preferably the ones that did not give birth within that year) and keep 5% more than that as replacement females.
6. Improving liveweight gain will reduce the time necessary to achieve marketable selling liveweights and consequently reduce the exposure of your animals to go missing (either thefts or dog attacks). For example, we plotted a conceptual scenario in Figure 26 where lambs in an improved system reach marketable liveweight in 6 months while in a current unimproved system takes 12 months. The six months extra required by the latter represents a greater risk for the farmer. Therefore, improvements in animal performance can potentially reduce the proportion of missing animals.

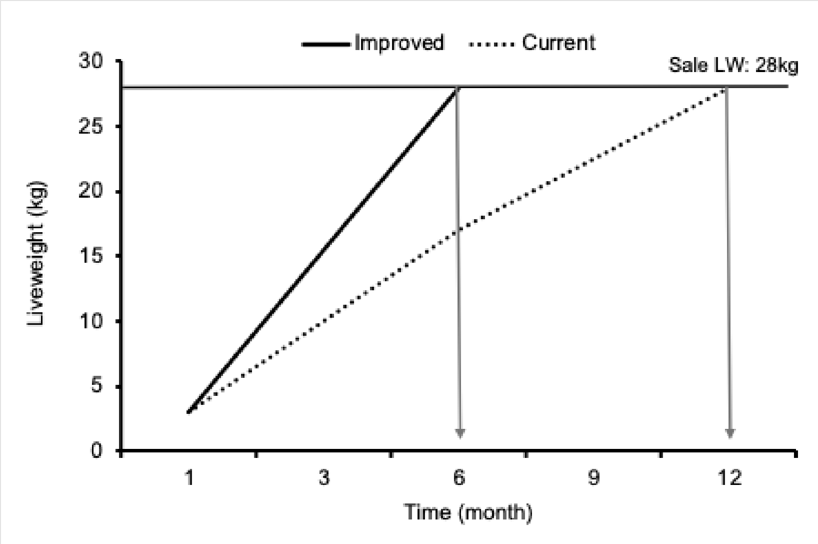

Figure 26: Conceptual effect of different growth paths on time exposure of small ruminants to thefts and dog attacks. Solid line represents growth path of an improved while the dashed line represents a current production system. The horizontal solid line marks the marketable selling weight and the vertical arrows points to the age at which animals will reach the marketable weight in each production system.

9.2.4 Methods for agricultural research-for-development

This project, as many others in the field of research for development in agriculture, have utilized of surveys and focus discussion groups as methods to collect information related to production systems, farm practices and household livelihood. Throughout this project we have noticed that on many occasions the information provided by farmers during this self-reporting situations was not in agreement with reality. A clear example of this behaviour was noticed when we asked farmers how often they would drench they small ruminant animals within a year. This question was asked in Fiji in two different surveys and in multiples focus groups discussion groups and the reporting has been consistently around once a month. However, this drenching frequency was not observed during the on-farm monitoring program when we followed 19 properties for at least one year and the drenching frequency has been much lower. We believe that farmers consistently reported to be drenching monthly because this used to be the recommendation provided by Ministry of Agriculture extension staff and therefore the “right answer”. However, there were many other situations which were hard to speculate the possible reason behind the obviously misleading report. For instance, during a certain focus group discussion a participating farmer reported to be purposely mating sheep with goats as a way to sell their offspring for a higher price - which is clearly absurd. Sheep and goats are of a different species and have different number of chromosomes. It is still possible that mating a sheep with a goat to produce a viable hybrid but the chances of it occurring in nature are extremely rare.

Another example of these discrepancies is the self-reported level of adoption of some management practices such as concentrate supplementation. The data provided in section 7.3 shows that approximately 30% of farmers in Upolu (Samoa) and Western division (Fiji) reported to utilize this practice. However, based on the expenditure recordings recorded during the on-farm monitoring program and observations made during the many farm visits conducted during the project, we can confidently attest that this adoption level is overestimated. In Samoa, we have asked farmers the type of ownership of their land (e.g. freehold, customary, lease etc..) and majority of farmers reported to have “freehold” while, after discussion with local researchers, it was found that most of the land reported as “freehold” was actually “customary”. And that reporting their land as freehold would portray them as of a higher social-economical class in their views. In Fiji, in conversation with farmers and results reported during the baseline survey shows that most farmers (> 60%) believe that anthelmintic resistance is a significant problem in their properties. We have heard farmers suggesting rumour's that the Ministry of Agriculture would dilute the anthelminthic drugs before selling to farmers – which again is an absurd hoax. All these claims and anecdotes led this project to undertake a large farm trial to investigate the level of anthelmintic resistance in these properties and found that despite being lower (91%) than the recommended threshold (95%) still provide a significant reduction in worm burden which doesn't justify the widespread belief that the commercialized anthelmintic (levamisole) is not effective.

It's not our aim to imply that all data generated by surveys or group discussions is flawed but to raise awareness to the risks of drawing definitive conclusions out of these data. While confronting the interviewee answers doesn't appear as a sensible option, triangulation of data from other sources and directly measuring the variable outcome seems more appropriate. This becomes even more relevant when dealing with production measures such as mortality rates or number of commercialized animals given that majority of farmers don't have records of these parameters and human memory is often very imprecise. All the points raised in this section reinforce the strength of the information provided by the on-farm monitoring program conducted during this project where the production parameters were calculated based on the long-term production recordings. Despite the inherit constraints (e.g. cost, time, lack of adherence etc…) that this type of data collection has, we believe it still produced a much more precise figure of production parameters.

10 References

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11 Appendixes

11.1 Appendix 1: Project booklet for on-farm monitoring.

11.2 Appendix 2: A Review of small ruminant research in Fiji and Samoa.

11.3 Appendix 3: Guidelines: Planting and utilization of leucaena and koronivia pastures.

11.4 Appendix 4: Gross margin analysis of small ruminant production in Fiji.

11.5 Appendix 5: Resistance status of six anthelmintic treatments in Fijian sheep and goat farms.

11.6 Appendix 6: Review of Ministry of Agriculture policies and regulations pertaining to small ruminant anthelmintic approval and distribution.