The Pennsylvania State University

The Graduate School

Department of Agricultural Economics, Sociology, and Education

PERCEIVED USES OF QUANTITATIVE GENETIC ANALYSIS AS A MANAGEMENT TOOL FOR SMALL RUMINANT PRODUCERS

A Thesis in

Agricultural and Extension Education

by

Michael Fiorentino

Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science

August 2019

The thesis of Michael Fiorentino was reviewed and approved* by the following:

Kevin Curry
Assistant Professor of Agricultural and Extension Education
Thesis Advisor

Anil Kumar Chaudhary
Assistant Professor of Agricultural and Extension Education

Chad Dechow
Associate Professor of Dairy Cattle Genetics

Laszlo Kulcsar
Professor of Rural Sociology and Demography
Department Head of Agricultural Economics, Sociology, and Education

*Signatures are on file in the Graduate School

ABSTRACT

The use of quantitative genetic analysis provides small ruminant producers with an invaluable tool to assessing the economic performance of their herds or flocks. The success of an effective breeding system is becoming increasingly reliant on the observation of economically functional traits which can be defined as traits related to growth, reproduction, health and product quality. Norris, Ngambi, Benyi, and Mbajiorgu (2011) suggested that an emphasis on traits for environmental adaptability, feed conversion efficiency, and reproduction will substantially benefit the industry.

The perceived uses of quantitative genetic analysis as well as the barriers inhibiting the adoption was analyzed using a descriptive research methodology. The population for this study was small ruminant producers in New York state. A convenience sample of 981 sheep and goat producers was used, however, response rates were only calculated for the 571 participants who successfully received a survey instrument. Of those producers, there was a total of 77 respondents for a 13.5% response rate. Data was collected through an online survey questionnaire administered through Qualtrics.

The data was analyzed using descriptive statistics to describe the characteristics of small ruminant producers in New York. Information about the farm status, the socioeconomic factors of production, and the psychosocial factors of the producer were collected and analyzed. A binary logistic regression was used to determine the predictors of small ruminant producers' intent to adopt the use of quantitative genetic analysis. The predictor variables identified in this study were not found to be significant indicators of small ruminant producers' intent to adopt the use of quantitative genetic analysis,

however, recommendations for small ruminant producers, Extension educators, and future research are identified.

TABLE OF CONTENTS

List of Tables

List of Figures

Acknowledgements

I am gratefully indebted to the support and mentorship I have received throughout this journey. My deepest gratitude goes to my advisor and committee chair, Dr. Kevin Curry for his dedicated commitment to helping me succeed. You consistently provided the support and encouragement to fuel my motivation and help me reach my potential. Your mentorship has bestowed me with guidance academically, professionally, and personally.

Thank you to Dr. Anil Kumar Chaudhary for contributing your extensive knowledge of research methodology and data analysis to this thesis. You provided incredible support and patience in helping me trouble-shoot and comprehend when it was most needed.

Thank you to Dr. Chad Dechow for contributing your expertise in animal science throughout the development of this thesis. Your thoughtful input helped shape the scope of this research.

Lastly, I would like to thank the rest of the faculty and staff that have contributed to my success here at Penn State. I would especially like to thank Dr. Rama Radhakrishna for taking me under his wing and introducing me to the world of research and scholarship.

The research reported in this thesis was supported by State Research Appropriations under Project #PEN04588 and Accession #1006716, the United States Department of Agriculture - National Institute of Food and Agriculture (USDA-NIFA).

The content is solely the responsibility of the author and does not represent the official views of the organization.

Chapter 1

Introduction:

The history of sheep and goat production in the United States dates back to the fifteenth century when the first animals were transported by English settlers. In 1607, the first sheep were imported to Jamestown, Virginia from England, however, due to a severe famine, most of the sheep imported were slaughtered for human consumption. Two years later in 1609, the first permanent flock was established in Jamestown, Virginia (Ensminger, 2002). Dutch settlers began establishing flocks of sheep in New York as early as 1625. However due to differences in climate these sheep did not thrive in North America. The introduction of sheep to the English colonies occurred well before the beginning of more conscious breeding efforts in England during the eighteenth-century. Consequently, many of the sheep that existed in the New World colonies were described as coarse, leggy, and late-maturing animals of primarily longwool varieties (Connor, 1921).

The arrival of goats in the United States was believed to have occurred around the same time by Spanish explorers. These Spanish goats that arrived were mostly feral and had little distinctive characteristics to them. However, in 1850 the Angora goat was brought over from Europe for its mohair, followed later around 1900 by the French Alpine, Saanen, Toggenburg, and Nubian goats and thus began the dairy goat industry in America (Christman, Sponenberg, & Bixby, 1997). In 1993, the United States meat goat industry was revolutionized by the introduction of the Boer goat breed, which had been

carefully bred in South Africa for exceptional growth rates and carcass characteristics (American Boer Goat Association, n.d.).

Over the past 400 years, the sheep and goat industry has made many advancements. Various breed organizations have been established to develop standards with the objective of progressing the breed in ways that transcend their ancestors for targeted traits. The United States Department of Agriculture (USDA) has established a set of standards to evaluate carcass quality and yield grades, which is dynamic to meet consumer demands. The USDA yield grade and quality grade standards assist consumers in choosing a meat cut that satisfies their preferences and allows producers to receive a fair price for the quality product they produce (Abraham, Murphey, Cross, Smith, & Franks, 1980). Systems for evaluating fleece and wool quality including the American Blood Grade System, Spinning Count System, and the Micron System have set guidelines to assist producers in developing high-quality fleeces for the fiber industry (American Wool Council, n.d.).

A traditional hand-and-eye method of evaluating livestock performance is described by Casey and Webb (2010); however, this method shows slow progression of genetic improvements for milk and fiber production (Norris, Ngambi, Benyi, & Mbajiorgu, 2011) as well as meat production (Department of Agriculture, Forestry, and Fisheries, 2012). The development of the National Small Stock Improvement Scheme has increased the rate at which genetic advancement is obtained by identifying correlations between the genotype of the animal and their phenotypic expressions (Olivier, Cloete, Schoeman, & Muller, 2005). The success of an effective breeding system is becoming increasingly reliant on observation of economically functional traits which can be defined

as traits related to growth, reproduction, health and product quality. Norris et al (2011) suggested that an emphasis on traits for environmental adaptability, feed conversion efficiency, and reproduction will substantially benefit the industry.

Small Ruminant Industry:

The United States has experienced a steady decline in sheep production since the industry peaked at 56.2 million head in 1942. Throughout the twentieth century the industry underwent an 86% decrease in the national inventory. The national inventory of goats in the United States does not show long-term trends for production since records only begin in 2002, however, according to the 2007 Census of Agriculture, there was a 24% increase in the national inventory from 2002 (National Agricultural Statistics Service, 2011). According to the USDA National Agricultural Statistics Service (National Agricultural Statistics Service, 2011), the national sheep inventory in 2017 was 5.2 million head and the national goat inventory was 2.64 million (National Agricultural Statistics Service, 2017). Of the national inventory of goats in 2017, 2.12 million head were raised for meat, 373 thousand head for dairy, and 152 thousand head for mohair production (National Agricultural Statistics Service, 2017).

The state of New York has seen an increase in the number of producers raising sheep and goats as a profitable enterprise over the past two decades. From 2002 to 2012 the number of producers in New York State increased by 13.65% and the annual revenue generated through sales of meat, milk, wool and mohair increased by 104.32% (United States Department of Agriculture, n.d.).

Goat Production

Goat production is ranked as the third largest global livestock industry directly after cattle and sheep production, as indicated by the number of animals reared (Morand-Fehr et al., 2004). The goat industry has grown since the end of the 20th century, with the largest increase in goat herd numbers in countries with low income (70%) (Morand-Fehr et al., 2004). Those countries with an intermediate income have grown their herd by 25%, while countries with a high income have grown by 20% (Morand-Fehr et al., 2004). Goats are popular in areas of limited resources due to their selective feeding behaviors and smaller size as compared to larger livestock species.

In the United States, the dairy goat industry has experienced tremendous growth in the number of animals raised; specifically, Wisconsin (10.6%), Texas (7.4%), and California (6%). While the growth trend continues across the United States, the production efficiency of dairy goat herds lags behind the dairy cattle industry when viewed in various agricultural economic models (Milani & Wendorff, 2011). A study of goat milk production in Wisconsin was conducted by the Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP) in collaboration with Iowa State University (Dietmann & Tranel, 2009). The study found that 41% of the surveyed dairy goat producers had only began milking goats in the past three years. The researchers project the growth of the industry to continue as 71% of the surveyed operations had plans to expand in the next five years (Dietmann & Tranel, 2009).

Outside of the United States, the goat industry has become important to the national economies of many countries such as those in the Mediterranean region, where the healthy and ecological image of the goat has become associated with the agritourism

(Boyazoglu, Hatziminaoglou, & Morand-Fehr, 2005). The production of goat milk in these countries is highly associated with the production of goat meat, which is a highly valued product with great nutritional value. Goat products continue to be the focal point of religious customs and have provided countless opportunities for new niches in developing markets and economies.

Sheep Production

Sheep have served humans for hundreds of years providing fleece and meat from land otherwise unfit for other agriculture sectors. Numerous breeds and hybrid-purpose composite breeds have been developed with the capacity for high levels of production under appropriate environments and management systems (Morris, 2009).

The United States dairy sheep industry is in its earliest stages of development. Sheep milk is not often consumed as fluid milk due to the high fat and solids content but is rather made into soft ripened and hard cheeses (Milani & Wendorff, 2011). Since the production of sheep milk is limited by seasonal breeding systems, shortened lactations, and low production per ewe, raw milk is typically frozen for up to six months or until a sufficient quantity is obtained for further processing (Milani & Wendorff, 2011).

There has been a universal decline in sheep populations over the past decade, especially in New Zealand and Australia, which have been the leaders of the sheep industry. Changes to the economy and climate factors have contributed to this decline – it is predicted that the short-term demand would not be satisfied by New Zealand or Australia, which would strengthen export prices in other countries (Morris, 2009).

Need for More Research on Small Ruminants:

Industrial growth has traditionally been viewed as the prime method of ensuring more wealth, more jobs, more happiness and prosperity (Dubeuf, 2014). Sheep and goats have often been used as a cost-effective catalyst in creating economic growth in underdeveloped countries due to their short production cycle, fast growth, and multiple functions (Peacock, 2005). As societal development increases and economic structures improve, this traditional paradigm loses credibility as new agricultural technologies focus more carefully on large-scale production, food safety, and sustainability (Dubeuf, 2014).

As the demand for arable agricultural land increases with the production of cash crops and protein sources such as cattle, swine, and poultry, the contribution of sheep and goats in meeting societal needs becomes increasingly important. Small ruminants thrive well on spaces often ignored by other agricultural sectors such as forests, rangelands, and interstitial spaces between crops and can often be integrated into these areas while still promoting positive ecological conservation practices (Dubeuf, 2014).

A case study of sheep production in New Zealand shows that climate conditions favor pasture growth, which can satisfy over 95 percent of daily dry matter intake in the diet of sheep (Morris, 2009). More intensive management practices have allowed annual lambing rates to increase significantly from 98 percent in 1987 to 125 percent in 2008 and it has been reported that sheep managed on improved lands have seen lambing percentages as high as 150 percent (Morris, 2009). Similar findings have been found in competitive pastoral regions (Montossi et al, 2013). Some key characteristics of the New Zealand sheep industry which make it a suitable model for other countries are low cost of production to allow for competitive export market prices, large flocks with low labor

inputs and efficient utilization of pasture, adequate subdividing of pastures to allow for controlled grazing, and ample availability of contract labor for specialized operations such as shearing and fencing (Morris, 2009).

Research on the efficient management of sheep and goats has lagged compared to cattle and swine – 33% of all technical papers published on goats around the world came from underdeveloped countries where 81% of the world goat population is produced (Morand-Fehr & Lebbie, 2004). In areas where little educational support resources are available, some producers have attempted to adopt findings from other livestock sectors to use in the management of their sheep flocks and goat herds with poor success. To maintain low costs of production in systems where feed resources are restricted or limited, some farmers in the Middle East have attempted to integrate conventional and unconventional feeds into their small ruminant rations – this has resulted in unbalanced protein levels which decrease growth consistency throughout growing animals and suppress invaluable energy supplies in lactating females (Iniguez, 2011).

On the contrary, research that has been focused primarily on small ruminants has been met with great success and led to the improvement of animal production and welfare. One study highlights the development of new technology for self-service complete-diet feed (SSCDF) rations for meat sheep (Olaizola, Chertouh, & Manrique, 2008). The farms that had adopted the use of the SSCDF system were family-run farms with very little outside household income. The average flock size for these farms was 690 sheep, which was 16.4 percent larger than when the farms had initially adopted the innovative practice – it was found that 47.8 percent of the farms had increased their flock size by an average of 44.3 percent (258 animals). In addition to the increase in

production, the farmers in the study had also reported a decrease in labor requirements; most farmers spent on average four to nine hours per day working on their sheep enterprise before the adoption of the SSCDF system and that was reduced to an average of one to five hours per day, dramatically increasing the overall quality of life as reported by the farmers (Olaizola, Chertouh, & Manrique, 2008).

Input from the producers in the industry is vital to the identification of research topics that are of most interest and benefit to the producers themselves. A check-all-that-apply survey questionnaire was developed to identify the lamb management practices being used and the barriers to implementing improved practices for resource-limited sheep farmers in South Africa (Lungu & Muchenje, 2018). Producer input from an assessment of dairy goat operations aided in identifying specific barriers to adopting more efficient herd management systems. Some of these barriers included the unavailability of quality genetics and the lack of a reliable goat-oriented dairy herd record management system when compared to dairy cattle (Dietmann & Tranel, 2009). A poor rate of return on assets, and milk prices that are below the cost of production even when comparing against the most cost-efficient production operations were additional barriers that were discovered (Dietmann & Tranel, 2009).

While research on improved management has become more prominent, the constraints that were identified will continue to inhibit the adoption of improved management practices if these are not addressed. Lamb mortality due to poor management practices contributed significantly to the lack of economic growth in this regional sector (Lungu & Muchenje, 2018), however, insight into the factors contributing to this cause can be addressed through greater educational campaigns.

For further research to be completed on small ruminant genetics, it is important for producers to keep sound records on the performance of their herds or flocks. In a study done on the Dorper breed of sheep in South Africa (Zishiri et al., 2013), researchers mined databases maintained by the National Small Stock Improvement Scheme that included over thirty years of data submitted by producers. This data was used to develop genetic parameter estimates for growth, reproduction and hardiness traits. Previous studies that have been conducted relied heavily on data that was either submitted by producers or collected by researchers. The development of an economically-sound breeding system and improvement programs relies heavily on the knowledge of genetic parameters for the production traits of economic significance (Safari, Fogarty, & Gilmour, 2005). Genetic parameter estimates become increasingly relevant when trying to define the breeding objectives of an operation, since heritability and covariance among traits may play an import role in the decision-making process. Gizaw et al. (2010), conducted interviews with producers in Ethiopia to identify the breeding objectives that were relevant in their region and scaled them by priority: 1) adaptation (resistance to parasites), 2) growth (yearling weight, mature weight, and average daily gain during finishing), 3) qumena (cultural preferences related to conformation style such as horn type and color), 4) reproduction (number of lambs weaned), 5) fleece (greasy fleece weight), and 6) milk production (yield). The breeding objectives defined by the producer was related to the function of their operation which were categorized as: regular cash income, financial/insurance benefits, socio-cultural importance, meat production, fleece production, manure production, and milk production. Many of these functions of

operations are relevant and are of similar priority to sheep and goat producers in the United States.

Developing estimates of heritability is vital to the use of a quantitative genetic evaluation system and has been performed by many researchers with comparable results. Research done on the heritability of traits found that many of the economically important traits of production have direct correlations with other traits such as weaning weight and mature weight of the animal (Safari et al., 2007), and growth and feed efficiency (Snowder & Van Vleck, 2003). It can be concluded that special attention to performance-related traits regarding breeding systems will play a significant role in the increase in efficiency of a production operation.

The promotion of beneficial management practices is essential for widespread adoption of innovative practices. Information diffusion to small ruminant producers may stem from various sources; Cooperative Extension Educators are one of the most direct routes of research-based knowledge from their designated Land Grant Institutions.

The Cooperative Extension System:

The Smith-Lever Act of 1914 established the Cooperative Extension System, a partnership between the federal government (United States Department of Agriculture), the state land-grant universities and colleges, and local governments (Seals, 1991). The mission and purpose of the Extension system is to disseminate the innovative research being performed at the university level throughout communities to enrich the lives of farmers and families across the nation. Funding for these services are provided by the

federal government and often supplemented, matched, or exceeded by state or local government financial support (Wang, 2014).

Extension educators have served communities in the areas of agriculture, food and nutrition, family and youth development, in addition to their contributions to the small ruminant industry. There is a positive correlation between participation in Extension services and achieving farm level outcomes (Cawley et al., 2018). Participation in Extension-run integrated pest management (IPM) workshops and classes has aided producers in managing parasitism in their herds or flocks and has contributed to the adoption of innovative tools such as the FAMACHA eyelid color scoring chart (Whitley et al., 2014).

The use of a public education service provides many economic benefits beyond the farm as well. Farms that operate more profitability will in return contribute monetary capital, employment opportunities, and improved livelihoods throughout their communities (Owens, Hoddinott, & Kinsey, 2003). The complete impact of Extension programs is difficult to measure since effects are often multifactorial, however, new systems are being researched to more accurately quantify the impact (Egziabher et al., 2011).

Extension educators are unique individuals – they are highly trained on specific subject area content, but also possess strong public speaking skills, are able to facilitate quality group discussions, understand information presented through the eyes of their clients, and have substantial enthusiasm and passion for their profession (Dodunski, 2014). Extension educators are thus well equipped to assist livestock producers in

integrating innovative quantitative genetic analysis strategies into their current management systems.

Purpose and Objectives:

The purpose of this study was to evaluate the perceptions of sheep and goat producers in New York State on the adoption of quantitative genetic evaluation as a management tool within their herds or flocks. For genetic progress to be made within a breed, wide-scale implementation of a more intelligent breeding-system must be utilized by a large number of breeders (Mohlatole & Dzomba, 2015). To increase the number of producers who are engaged in the practice of quantitative genetic analysis of their herds or flocks, there is a need to identify the barriers that are preventing small ruminant producers from adopting this innovation. Through understanding the barriers to implementation, future attempts to engage producers in the practice can overcome those barriers and increase participation in the programs available. While there are organizations established that will convert raw data into selection indices and EBVs for producers, the on-farm evaluation of animals using this strategy is also possible and is encouraged.

This research study is guided by the following objectives:

1. Describe the farm status of small ruminant producers in New York State.
2. Describe the socio-economic factors of small ruminant producers in New York State.
3. Describe the psycho-social factors of small ruminant producers in New York State.

4. Identify barriers that may inhibit the adoption of quantitative genetic analysis strategies for small ruminant producers.
5. Evaluate the influence of farm status, socio-economic factors, psycho-social factors, and barriers as predictors for the adoption of quantitative genetic analysis strategies for small ruminant producers.

Operational Definitions:

Economies of Scale: The savings in costs gained by an increase in production.

Economies of Scope: The savings gained by producing two or more distinct products, when the cost of doing so is less than the cost of producing each separately.

Economic Resilience: The ability to withstand or recover from an unexpected change in the market.

Psychosocial: The interrelation of social factors and individual thought and behavior.

Quantitative Genetics: The measurement of total phenotypic variance caused by the interaction of genetic information with environmental influences.

Summary:

While the global population of small ruminants is experiencing a decline in production, the state of New York is seeing a healthy growth in their herd and flock sizes. There are many challenges that pose threats to the small ruminant industry: a volatile economy, decreased efficacy of anthelminthic drugs, and the risk of mortality or morbidity from disease. Opportunities to decrease the risk of these threats exist;

increasing the genetic resilience of small ruminant herds and flocks through the innovative process of quantitative genetic analysis will be described in chapter two.

Chapter 2

Chapter two begins with an overview of the small ruminant industry and the challenges that are faced. The need for more research on the adoption of quantitative genetic analysis in small ruminants is established. The theoretical framework and a review of literature used in the development of the conceptual framework for this study are detailed throughout the chapter.

Challenges Facing the Small Ruminant Industry:

Economics

With the changing growth of the small ruminant industry, it is important to begin placing a higher emphasis on the economic factors of production (Mohlatole & Dzomba, 2015). An examination of the costs of production and levels of return on a per animal basis revealed that the Eastern United States has the highest production cost in the nation (Williams & Anderson, 2016). To keep a competitively-priced product in the market, producers must either sacrifice the level of profit received or focus on innovative ways to decrease expenses and increase revenue within their operations.

On a global-scale, Sweden is currently producing only 37% of the lamb and mutton consumed in their country, however the Swedish slaughter industry seeks to increase the production of local lamb (Kumm, 2009). An economies of scale model was estimated for Swedish lamb production by calculating the profitability for various sized farms slaughtering lambs from late winter to early summer. To realistically model the limitations of the intensive production style of indoor feeding and strict animal welfare regulations, multiple lambing times from December to April with the slaughter of early born lambs before the birth of late season lambs was assumed to reduce building space

requirements (Kumm, 2009). The main costs associated with the sheep operations were feed, infrastructure, and replacement ewe costs – additional costs included minerals, animal health expenses, and interest on funds invested in the operation (Kumm, 2009).

The most severe obstacle for the expansion of flock sizes was found to be the lack of affordable pastures and fields for silage production (Kumm, 2009). New facilities can be constructed to support increased flock growth, however a one-time purchase of a large quantity of ewes or a high level of home-grown replacement ewes is required to justify the full capital cost of buildings and maximize return-on-investment. Regardless of method of expansion, growth sacrifices are inevitable as a high percentage of replacement ewes results in a low selection pressure and a large portion of young animals in a flock leads to decreased production levels. Given the previously described growth limitations, the economies of scale model illustrates that at least 500 ewes are required to break even when newly constructed facilities are appraised at fair market value and depreciation costs are dispersed over multiple years (Kumm, 2009). While some of the limitations discussed in the study are unique to the Swedish environment, many of these challenges are also relevant to the United States and could influence the economies of scale required to increase the U.S. production of both sheep and goats.

The European Union has also experienced economic challenges across their agricultural production sectors in response to a reform of the Common Agricultural Policy (Castel, Ruiz, Mena, & Sanchez-Rodriguez, 2010). Financial assistance was previously divided amongst farms in each agricultural sector; however, the reform revised the economic assistance program so financial aid is provided to farms contingent upon farm practices leading toward environmental conservation, animal welfare, and

food safety. The production of sheep and goats in Spain is often integrated into other livestock enterprises as goats are reared extensively. Natural pastures, often located in mountainous regions, are used for grazing with limited supplementation of forage with concentrates. Attempts to modernize the production of small ruminants in these regions have had setbacks, since animals bred for the increased production of meat and milk often do not thrive under these extensive management conditions. Additional limitations for the expansion of the Spanish sheep and goat industry include low education level of farmers, limited Extension services, low quality of life for the producers, and poor structure of the small ruminant sector especially in the marketing of sheep and goat products (Castel et al., 2010). While the ability for small ruminant producers in Spain to qualify for the revised financial assistance programs may be limited, there are many opportunities for them to take advantage of the new policies to reinforce the sheep and goat sector, improve the quality of life of farmers in the region, and strengthen the development as research in these industries (Castel et al., 2010).

Disease

Disease has always been a cost-inhibiting factor of sheep and goat production – the effects of morbidity and mortality in animals of all ages results in an economic loss to the producer. Significant advances have been made in the prevention and treatment of diseases over the past century with the development of improved anthelminthics, antimicrobials, and non-steroidal anti-inflammatory drugs (McKellar, 2006). While novel advancements have been made in the research and invention of new drugs, the cost of regulatory testing to ensure human safety and the low economic influence of sheep and

goat production compared to larger livestock industries have severely limited the availability of these products to both veterinarians and small ruminant producers.

Disease threats are classified at three levels: 1) threats to the national herd or flock, 2) threats to individual herds or flocks, and 3) threats to individual animals (Roger, 2008). Disease can be caused by environmental factors, nutritional excess or deficiencies, or genetic predisposition (Roger, 2008). The proper prevention and management of disease requires careful thought and planning – producers should be aware of common diseases and ailments that may become present in their herd or flock and develop protocols to isolate and eliminate affected animals early on, in addition to establishing a confident veterinarian-patient relationship.

Caseous lymphadenitis (CL) is a disease caused by a specific bacterium that infects sheep and goats. This disease causes abscesses to develop along lymph node areas which results in a decreased carcass value due to necessary trimming of infected areas. In a ram circle in Norway, where a group of 17 farmers shared 33 rams to cover their combined flock of 1900 ewes, 21 of the rams exhibited clinical symptoms of the infection after grazing a shared pasture during the non-breeding summer months (Hektoen, 2012). To prevent the spread of the infectious bacterium to the entire ewe flock, all 33 rams were culled, and post-mortem examinations revealed that all of the rams, including the ones that did not exhibit clinical symptoms of infection were seropositive for *Corynebacterium pseudotuberculosis*, the bacterium that causes the CL abscesses.

As a result of the economic loss experienced from the culling of the entire male breeding flock, the farmers were highly motivated to develop and begin implementing a plan to eliminate the occurrence of CL abscesses from their flocks. False negatives can

occur in both clinical examinations and serology tests, however the repetitive use of the combined methods in addition to reducing the risk of transmission of bacteria within and between flocks can yield successful results. After implementing the intense plan of action and culling infected animals from the flock, the prevalence of CL abscesses within the flock reduced to a range of zero to ten percent (Hektoen, 2012).

Providing small ruminants with proper nutrition, sanitary living conditions, and administering vaccines when recommended by a veterinarian can dramatically decrease the cost associated with treating disease and the economic loss of decreased production. Proper selection of replacement animals and culling of unthrifty or underperforming animals from the herd or flock can aid in increasing the overall herd or flock health and allow for the identification and promotion of animals that are more genetically resilient to the effects of disease.

Anthelmintic Resistance

Parasitic infections and infestations can adversely affect the production efficiency of small ruminants. Gastrointestinal nematodes are of greatest significance to producers as high levels of infection may cause decreased feed intake, decreased growth in kids, and reduced reproductive performance in both male and female stock (Fthenakis & Papadopoulos, 2018). The most common clinical symptoms of infection include body weight loss, diarrhea, rough hair coat, weakness, and anemia. Heavy infestation of parasites can also predispose infected animals to other diseases, leading to a further decrease in economic performance and increase treatment costs (Fthenakis & Papadopoulos, 2018). Fecal egg counting has become a routine practice to confirm infection when other clinical symptoms are present.

Anthelmintic resistance, or the decreased efficacy of the drugs used to treat these gastrointestinal nematodes, is becoming a global issue in the small ruminant industry. The Tennessee State University conducted a study of 90 young meat goat females managed on pasture to determine their level of resistance to four common drugs from three anthelmintic classes. A Fecal Egg Count Reduction Test (FECRT) revealed that parasitic resistance existed for all three classes of anthelmintic drugs (Goolsby, Leite-Browning, & Browning Jr, 2017). It was recommended that alternative methods of gastrointestinal nematode management be evaluated for use to eliminate the sole reliance on anthelminthics for control.

Similar to other management tools, fecal egg counting must be used complimentary to proper record keeping, observation of clinical symptoms, and herd or flock treatment history. While gastrointestinal nematodes may be identified through fecal egg assessments and levels of infection may be determined, the assessment fails to take into consideration the economic threshold that infection or infestation begins to adversely affect animal health. Culling animals that exhibit clinical symptoms of infections allows the animals in the herd or flock that are more resilient to infection to continue to genetically contribute to the herd or flock (Sargison, 2013).

While most research on the control of gastrointestinal nematodes focus primarily on the fecal egg count reduction tests, a recent study suggests the use of statistical distribution models to select animals more resistant to parasitic helminths (Sebatjane, Njuho, & Tsotetsi-Khambule, 2018). The presence of internal parasites was frequently higher in goats compared to sheep. Common covariates used to determine the prevalence of parasites include season, host age and sex, and location. Rainfall, season, and location

were the predominant factors determining the distribution of parasites amongst their hosts (Sebatjane, Njuho, & Tsotetsi-Khambule, 2018).

Attempts to reduce the economic impact of anthelminthic resistance may be accomplished through the development of new drugs or the restriction of drug availability to only trained professionals. However, a sustainable alternative remains selecting animals resilient to the adverse effects caused by parasitic infection. Repeated treatment of infected animals gives an unfair advantage in phenotypic appearance and does not allow for the proper selection of animals genetically resistant to parasitic infection (Ngere et al., 2017). Fecal egg count data can successfully be used to create selection indices for parasite resilience, however for this method to be effective, a larger reference population of sheep and goats are required. It is proposed that the adoption of quantitative genetic analysis tools will aid small ruminant producers in reducing the economic effects of anthelmintic resistance in their herds or flocks.

Use of Quantitative Genetic Analysis in Sheep and Goats:

Numerous studies have been performed to assess the importance of an animal's performance in predicting the heritability of production-specific traits in multiple livestock sectors (Mohlatole & Dzomba, 2015; Norris, Ngambi, Benyi, & Mbajiorgu, 2011; Mulder, Bijma, & Hill, 2007). The use of performance traits in evaluating the genetic merit of an animal has shown improvement in economically-valuable traits such as growth, reproduction, health, and product quality (Mohlatole & Dzomba, 2015).

The standard genetic model in quantitative genetics is that phenotype (P) is the sum of the genotype (G), the environmental influence (E), and the interaction of G and E

(Yang et al., 2015). When evaluating the effect of genotype in the standard model, environmental variances are assumed to be constant (Mulder, Bijma, & Hill, 2007). It has been reported, however, that environmental variance does play a significant role in genotypic expression (SanCristobal-Gaudy et al., 2001) due to the interaction of G and E. Recent research has revealed the connections between epigenetics and phenotypic expression of traits. According to Triantaphyllopoulos, Ikonomopoulos, & Bannister (2016), the current knowledge of genomics in livestock implies that the expression of desirable traits is solely dependent on the DNA sequence. However, phenotypic disruption of quantitative trait expression can be compromised by improper imprinting. Fortunately, the effect of these variances on predicting the genetic merit of an animal can be reduced due to a further understanding of the genome sequences in livestock (Jaenisch & Bird, 2003).

The use of validated quantitative genetic analysis techniques allows the producer to evaluate livestock performance without requiring an advanced knowledge of genetics. The factors that may be inhibiting the uptake of this strategy have not been documented in the literature; proposed factors may include a lack of available information resources available to producers on the genetic parameter estimates for small ruminant production traits and a lack of knowledge amongst the producers on how to effectively develop the algorithmic equations to use quantitative genetic analysis.

With an increase in the numbers of producers engaging in the production of small ruminants, higher priorities must be placed on the economic factors of production including the rising costs of production relative to product prices (Mohlatole & Dzomba, 2015). To increase the efficiency of a breeding system, emphasis on the performance of

individual animals must be assessed to identify the animals within a herd or flock that possess superior qualities. Disease can lead to instances of mortality and morbidity which ultimately result in economic loss for the producer. Fortunately, through specific selection, animals that are more resilient to parasites and disease can be developed and contribute significantly to the success of the herd or flock (Mohlatole & Dzomba, 2015).

The methodology supporting the use of an evaluation of production traits in making breeding decisions relative to improving the cost efficiency of livestock operations has been established in research (Nielsen et al., 2010). New Zealand and Australia have paved the road to genomics in small ruminants with the development of software such as LAMBPLAN® that will perform an analysis of performance data to create an index comparing all the individual animals within a breed. The United States has followed suit and has worked closely with Sheep Genetics of Australia, the creators of LAMBPLAN® to develop the Pedigree Master® software available through the National Sheep Improvement Program (NSIP). The data collected by individual herds or flocks can be transmitted into an estimated breeding value (EBV) that will evaluate superior animals from multiple herds or flocks within a breed, while controlling for environmental bias. Currently, EBVs are processed by the NSIP for weight traits, wool traits, body composition, reproduction, and parasite resistance. The NSIP has also developed indices for producers to evaluate sheep breeding stock through the Western Range Index, which is used primarily in Targhee flocks, and the Ewe Productivity Index, which is targeted for Katahdin and Polypay breeders (Notter, 2011).

The EBVs provide an unbiased evaluation of an animal's performance for many breeds of sheep, as well as meat goats. The system will control for environmental factors

such as birth-rearing type and age of dam at time of parturition using multiplicative adjustment factors derived from population-wide factors of both high-performing and low-performing herds or flocks. This is an asset for producers who are selecting sires from other breeders to contribute to the genetic advancements of their own herds or flocks. However, for an EBV to be calculated accurately, herds or flocks should be utilizing multiple bucks or rams to effectively compare progeny. To further increase accuracy, breeders may combine efforts and collaborate with other smallholder farms in sharing bucks or rams; therefore, the progeny of the selected sire can be evaluated widely across multiple herds or flocks which may vary in the extrinsic factors of production (Notter, 2016).

Need for Further Research:

To encourage more producers to engage in the adoption of quantitative genetic evaluation as a management tool, it is necessary to first identify the barriers that exist that are inhibiting the rate of adoption. Kairu-Wanyoike et al. (2013), identified that the knowledge, attitude, and practices of the herdsman in Kenya directly influenced their adoption of preventative measures regarding contagious bovine pleuropneumonia. It was also identified that the socio-economic status of the producer as well as the psycho-social factors influenced the uptake of the innovation.

To gain an accurate perspective on the pathway for sheep and goat producers to readily adopt these innovative practices, a new model is to be developed through a combination of existing models of human behavior. These existing models are described in detail followed by a proposed conceptual framework that will be used in this study.

While these existing models have been validated across multiple disciplines, there is no current model that exists that applies specifically to small ruminant producers.

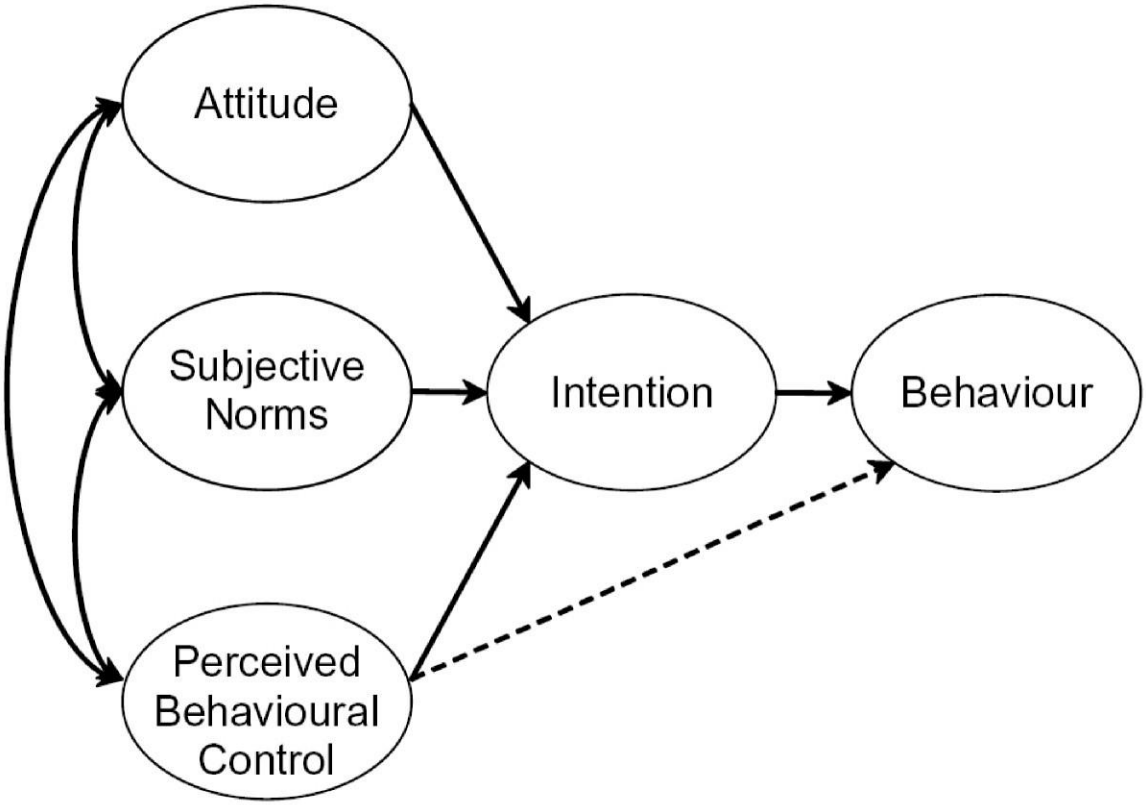
Theoretical Framework:

Theory of Planned Behaviors

The Theory of Planned Behaviors (Azjen, 1991) illustrates the relationship between intention and action and how intrinsic factors will affect behavioral change. This theory also explains the extrinsic roles that significantly impact progression once intent to adopt the new behavior is obtained. According to Azjen, the centralized factor of the Theory of Planned Behavior is the individual's intention to perform a given behavior. The measure of an individual's intention is captured by the motivational factors that influence the behavior which indicate the degree of effort they are willing to commit. However, an individual's performance is greatly influenced by other non-motivational factors such as availability of requisite opportunities and resources (Azjen, 1991).

The Theory of Planned Behavior (figure 2-1) depicts three conceptually independent determinants of intention: 1) attitude toward the behavior, 2) subjective norm, and 3) perceived behavioral control. The individual's *attitude toward the behavior* refers to their evaluation or appraisal of the behavior with disregard to their level of awareness or knowledge of the subject. The *subjective norm* is the perceived social pressure that an individual experiences to perform or not perform a behavior. Lastly, the *perceived behavioral control* refers to the perceived ease or difficulty of performing the behavior, although, perceived behavioral control may not be realistic when a person has little information about the behavior, when required or available resources have changed, or when unfamiliar elements have entered the equation (Azjen, 1991).

Figure 2-1: The Theory of Planned Behavior. (Azjen, 1991).



In a study of Brazilian cattle farmers (Borges, Lansink, Ribeiro, & Lutke, 2014), the psychological constructs of the Theory of Planned Behavior was applied to understand the farm owners' intent to adopt natural grazing practices. The results of the study showed that the constructs of attitude, subjective norm, and perceived behavioral control were all positively and significantly correlated with intention. These principles can be applied in theory to small ruminant producers who are working in a similar volatile environment.

In educating livestock producers on the use of these innovative practices, it is important to not only focus on the economic advantages that may exist, but also focus on

the social aspect of the innovations. The successful uptake of an innovative practice is dependent on the level of effort the individual is willing to commit to achieving the behavioral change. The perceived usefulness of the innovation is a key factor in determining whether or not an individual will accept the new product or concept; however, achieving the intent to adopt new practices is more influenced by social factors such as opinions of relevant figures and the interactions between farmers and stakeholders (Naspetti et al., 2017). There are numerous factors that can cause reverse effects once intent to make a behavioral change is achieved. It has been suggested that adoption behavior should be measured and modeled on a continuous process to incorporate social norms and uncertainty into the decision-making process (Liu, Bruins, & Heberling, 2018).

Review of Literature:

Farm Status as a Predictor of Innovation Adoption

The ability for farmers to structurally adjust to changes in the economics of commodities and society is significantly dependent on the flexibility of the farm enterprise system (Happe, 2004). Economic resilience can be improved through diversifying the agricultural operation in the event that one of the enterprises of the business experiences a short-fall in cost-return or another unplanned catastrophe. The economic performance of a successful agricultural operation is significantly influenced by the abilities of the farmer in managing resources and adapting to new technologies (Fernandez-Cornejo, Nehring, Hendricks, Southern, & Gregory, 2007).

The ability for small ruminant producers to readily adopt the practice of quantitative genetic evaluation into their existing herd management system may be

influenced by the size of their herd or flock. Small herds and flocks have the advantage of the potential for a closer evaluation of each individual animal, while on the contrary, may not have the luxury of culling the percentage of animals required to experience the full benefits of the improved evaluation system (Holst, 1999). Larger herds or flocks will have their own advantages and disadvantages as well – the increased number of animals may reduce the frequency of obtaining performance records due to the increase in labor requirements (Cappai, Picciau, Nieddu, Bitti, & Pinna, 2014), however, may be able to see the improved benefits of the system quicker as a result of a larger reference population contributing data to the algorithmic equation.

Farm size has been validated across various agricultural sectors as a significant predictor of innovation adoption: Evidence can be found in the industries of dairy cattle (Khanal, Gillespie, & MacDonald, 2010; Gargiulo, Eastwood, Garcia, Lyons, 2018), crop production (Epplin & Tice, 1986), meat goats (Gillespie, Qushim, Nyaupane, McMillin, 2015), beef cattle (Sun, Hyland, Bosch, 2014), and swine (Valeeva, Van Asseldonk, Backus, 2011). Larger farm size has allowed the opportunity to more readily try new innovations since larger farms have more opportunities for diversification (McInerney & Turner, 1991), have a higher absorptive capacity, and possess greater social capitol (Micheels & Nolan, 2016).

Socio-Economic Factors as a Predictor of Innovation Adoption

There can be a large financial commitment when starting a small ruminant enterprise. Purchasing animals, renting/purchasing land, investment in infrastructure, etc., as well as the cost of maintaining an operation which includes purchasing feed, maintaining equipment, paying for labor, etc. are all expenses that may be encountered

(Gillespie, Qushim, Nyaupane, & McMillin, 2015). Since the operational costs of running an enterprise varies greatly amongst producers, the profitability of the farm is dependent on the management style of the individual operations.

Improving the profitability of an enterprise requires flexibility and ingenuity as each farm is operating under different conditions and restraints. In a study of small-scale dairy farms in Mexico, it was found that wealth status was a significant factor in predicting the adoption of innovative management practices – it is also noted that the higher the wealth status of the farmer and the more innovative practices they applied, the greater the profitability of their farm increased (Garcia, Martinez, Dorward, & Rehman, 2012). Another study in Kenya developed a regression analysis to determine how the socio-economic status of the producer influenced the overall health of their small ruminant herd (Moore, Folwell, DeBoer, Bari, & Mbweria, 1991). It was found that producers who sold their livestock as a main source of their income had herds with lower strongyle egg counts. The farmers in this category also had a strong tendency to sell animals that were either in marginal health, or poor condition – this suggests that animals that began exhibiting clinical symptoms of gastronematode infection were likely removed from the farm, which increased the overall health of the remaining herd. In contrast, many farmers who had received household income from family members who worked off the farm had higher oocyte levels in their fecal egg counts. While the contribution of outside sources of income could financial support the use of anthelminthics or veterinary services, it also creates a labor restraint for the remaining family members working on the farm (Moore et al., 1991).

The contribution of an off-farm source of household income may provide producers a safety-net when it comes to the financial dependency of their farm enterprise to support the livelihood of themselves and their families and increase their resilience to economic shock. The decision to participate in off-farm work as a means of financial support or ability to obtain employee benefits is positively related to the age of the producer, their level of education, and spouses' lifestyle (Fernandez-Cornejo, Hendricks, & Mishra, 2005). Farmers who rely more heavily on off-farm sources of household income experience a trade-off between economies of scope and economies of scale – since farmers who participate in off-farm work consequently have less time to devote to their agricultural operation, the decision to adopt an innovative product or technology becomes more influenced by increased convenience rather than increased profitability (Fernandez-Cornejo, Hendricks, & Mishra, 2005).

Psycho-social Factors as a Prediction of Innovation Adoption

The influence of various psycho-social factors involved in sheep and goat producers' ability to successfully implement an innovation has been suggested in the literature (Kairu-Wanyoike, et. al., 2013). In one recent study, the term psychosocial factors are defined as "psychological processes interacting with social contextual forces to shape behavior" (Andrews, 2017, p. 445).

The psycho-social factors that were of interest in the present study were *satisfaction*, defined as the small ruminant producer's feelings towards their farm enterprise, and *goals*, defined as the producer's goals for improving their operation. The questions on the satisfaction index measured the feelings of the small ruminant producers regarding farm profitability, overall herd or flock health, degree of decision latitude, and

intent to continue raising sheep or goats. A study of Australian farmers had investigated the relationship between a farmer's wellbeing and their intention to leave the farming occupation (Peel, Berry, & Schirmer, 2016). It was found that farmers' experiencing a poor wellbeing were more likely to leave their farming occupation – factors amongst these farmers that were associated with poor wellbeing included: less profitable farmers, younger farmers, farmers with larger farms, and farmers who earned low-to-moderate proportions of their household income off-farm. These observations are important to note since farmer's who are experiencing poor wellbeing or dissatisfaction towards their work environment are less likely to place value on innovative ideas or practices (Saxby, Gkartzios, & Scott, 2017).

Ritter, Adams, Kelton, and Barkema (2019) conducted a study of dairy farmers' satisfaction with the herd health and production consultancy provided by their primary veterinarian and their preparedness to adopt the recommendations that were made. Some of the highest rated factors associated with the preparedness to adopt the recommended practices included: involvement during appointment, veterinarian's confidence, involvement in decisions, and explanation of treatments and procedures. The lowest rated factors associated with preparedness to adopt recommendations were discussion of cost, understanding of costs, discussion of options, and amount of information received. The findings from this study could be translated in theory to the interactions between Extension educators and small ruminant producers and the preparedness to adopt methods of quantitative genetic analysis, however, this relationship must be further analyzed to confirm.

A producer's goals for their operation relates to their intentions – a measurable outcome and precedent to behavioral change in the theory of planned behavior. Goals and objectives established by farmers can be used to accurately predict behaviors and intent to adopt innovative practices (Bergevoet, Ondersteijn, Saatkamp, van Woerkum, & Huirne, 1995). Bergevoet et al. (1995) report in a study of Dutch dairy farmers that the intent to achieve the image of a large, modern farm was more influenced by non-economic goals such as enjoying work, working with animals, and producing a safe product compared to the economic goal of achieving maximum profit, as a traditional economic model of decision making would suggest.

Farmers goals are often multifaceted and collaboratively influence their decision-making behavior (Cary & Holmes, 1982). Goals can be hierarchal in nature which implies that either they must be achieved in a logical order or that the satisfaction of smaller goals will motivate producers to achieve larger goals. The goals of Australian farmers were found to be categorical; income goals related to making a profit or safeguarding future capital were found to be of higher priority compared to goals such as recognition or continuing tradition (Cary & Holmes, 1982). While the priorities of the goals and intentions of small ruminant producers may vary from individuals in other agricultural sectors, improving the financial sustainability of an enterprise may have benefits that trickle-down into other aspects of their lives in addition to providing a direct benefit to the operation.

Conceptual Framework:

After careful study of theoretical models of human behavior (Azjen, 1991) and a review of relevant literature, a conceptual framework was developed to understand the

perceptions of sheep and goat producers in utilizing a system of quantitative genetic analysis. The proposed conceptual framework is illustrated in figure 2-2.

The use of a more intelligent breeding tool such as quantitative genetic analysis would allow sheep and goat producers to develop increased confidence in the decisions they are making relative to the profitability of their enterprise. By allowing for a more transparent and unbiased method of selecting superior animals from one's herd or flock, sheep and goat producers will experience a greater sense of autonomy, competence and relatedness in their herd or flock management; the three key factors related to positive wellbeing (Ryan, 2009). The support of positive wellbeing in addition to the elimination of negatively-influencing psychosocial factors will positively impact the degree of implementation for an innovative tool such as quantitative genetic analysis.

The Theory of Planned Behavior demonstrates the pathways to achieving a specific behavioral intention and eventually a behavioral change outcome. The proposed conceptual framework (figure 2-2) illustrates three variables that may influence the factors contributing to the individual's intent to adopt a behavior. The three variables include the farm status of an operation, the socioeconomic factors of production, and the psychosocial factors of the producer.

The farm status of the operation in this study is defined by the purpose of the animal being raised and the herd or flock size. Similar to the other variables listed in the model, the farm status is believed to influence *attitude towards a behavior*, *subjective norm*, and *perceived behavioral control*. The producers' attitude towards the use of quantitative genetic analysis may be influenced by its relevancy to their operation. For producers who aren't concerned with improving the genetics of their herd or flock, this

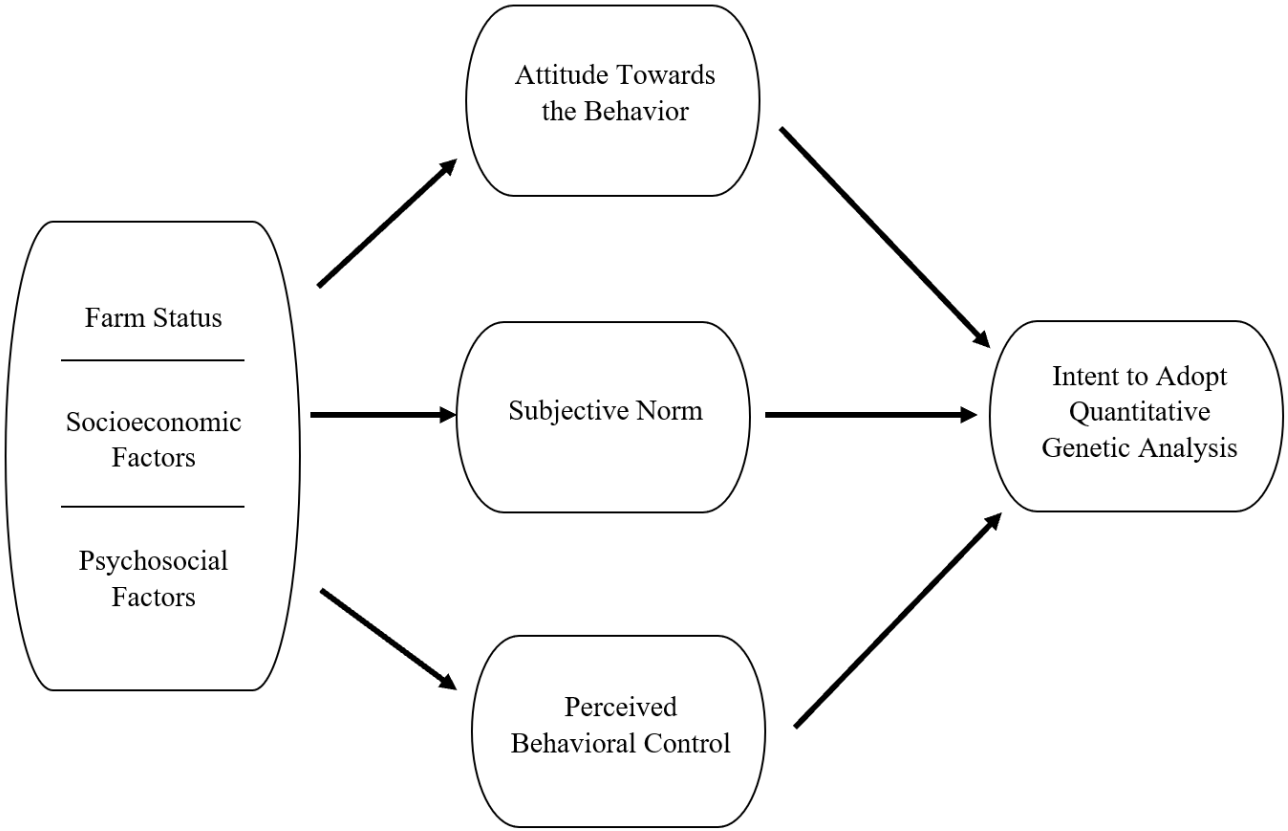
particular practice may not be well perceived. The subjective norm, or the social pressure to adopt an innovation, may also be influenced by the farm status. Depending on the type of animals being produced, societal pressure to utilize performance data such as EBVs as a livestock marketing tool may be a motivating factor to make the adoption. Lastly, the status of the operation may influence the producers' perceived behavior control, which is also defined as the perceived ease or difficulty associated with the adoption. The producers' farm size may be correlated to their confidence and knowledge of their current management system and marketing strategies, which may influence their decision to adopt innovations.

The socio-economic factors of the operation are related to the profit received for products being marketed and the contribution of income from the farm enterprise towards the household income. This variable is also believed to influence the factors of *attitude towards the behavior*, *subjective norm*, and *perceived behavioral control*. The level of profit that the producer receives from their sheep or goat products and the amount of that profit that is contributed towards their household may greatly influence their appraisal of their small ruminant operation. Producers who rely more heavily on their operation to support their families and livelihoods may respond to new innovations differently than others who do not make a profit on their operation. The subjective norm of having a profitable business and marketing high-dollar animals may positively contribute to the decision to adopt a more intelligent management tool. In addition, investing into a management system that allows for a more transparent evaluation of livestock may increase the perceived ease of transitioning into a new system.

The third variable influencing the attitude towards the behavior, subjective norm, and perceived behavioral control is the psycho-social factors of the producer. The psycho-social factors are measured in this study as the satisfaction of the producer and the goals of the operation. Satisfaction towards the operation can influence a producers' appraisal of an innovation in many ways; someone who is satisfied with their current management system may either not see the need to introduce a new innovation, or on the other hand, feel confident in taking the next step to progress their operation. The social pressure, or subjective norm, of continually achieving the most innovative system may be incorporated into the goals and objectives of the operation and highly influence the decision to adopt a new innovation. Finally, the perceived ease or difficulty associated with adopting an innovation may be related to the current adversities being faced on the farm. Producers who are constantly coping with existing challenges may not be willing to adjust to a new system if the perceived usefulness does not exist.

Figure 2-2 illustrates how these variables are integrated into the Theory of Planned Behavior. The independent variables are measured on the constructs of farm status, socio-economic factors, and psycho-social factors. The independent variables are farm size and animal purpose (farm status), annual profit and contribution of farm profits to household income (socio-economic factors), and goals of the operation and satisfaction of the producer (psycho-social factors). The use of these constructs in influencing the dependent variable, intent to adopt quantitative genetic analysis, was explored through this study. The proposed conceptual model illustrates that any of the constructs would independently improve the likelihood of achieving the intent to adopt, however, the interaction of all three constructs would greatly increase that likelihood.

Figure 2-2: Proposed Conceptual Framework



Chapter 3

This chapter presents the research methodology used in this study. The chapter describes the population and sample selection, instrumentation, validity and reliability of the instrument, survey administration timeline, and data analysis procedures.

Purpose and Objectives:

The purpose of this study was to evaluate the perceptions of sheep and goat producers' in New York State on the adoption of quantitative genetic evaluation as a management tool within their herds or flocks.

This research study was guided by the following objectives:

1. Describe the farm status of small ruminant producers in New York State.
2. Describe the socio-economic factors of small ruminant producers in New York State.
3. Describe the psycho-social factors of small ruminant producers in New York State.
4. Identify barriers that may inhibit the adoption of quantitative genetic analysis strategies for small ruminant producers.
5. Evaluate the influence of farm status, socio-economic factors, psycho-social factors, and barriers as predictors for the adoption of quantitative genetic analysis strategies for small ruminant producers

This research utilized a descriptive survey methodology and evaluation of quantitative data to answer these questions.

Population:

According to a 2012 agricultural census (United States Department of Agriculture), there were approximately 3,604 sheep and goat producers raising animals for either meat, milk, or fiber within New York State. A convenience sample of approximately 981 sheep and goat producers from New York State was utilized for this study. A convenience sample was chosen because identifying and obtaining contact information of each small ruminant producer in the state was not feasible; while estimates of herd or flock inventories exist, there is not an exact record of individuals engaged in the production of sheep or goats that exists. The individuals that were invited to participate in the survey were identified through a database provided by the Cornell University Sheep and Goat Program and screened for eligibility. Producer information compiled in the database was voluntarily provided to the program through either participation in a Cornell University Sheep and Goat Program sponsored event or subscription to a *sheep and goat management* or *small ruminant marketing* e-mail listserv. An initial screening of participants allowed for the identification of sheep and goat producers who reside in New York State and had available e-mail contact and physical mailing address information listed. It is important to note that not all individuals who attend Cornell Sheep and Goat Program sponsored events or subscribed to receive information from the program are currently engaged in the production of sheep or goats themselves.

Instrument:

The quantitative data for this study were collected through a survey questionnaire (Appendix A: Survey Instrument) administered through Qualtrics®, an online platform

that manages survey research instruments. The questionnaire explored three major constructs: (1) status of the operation, (2) socio-economic factors of the producer, and (3) psycho-social factors of the producer. The status of the operation was determined by the size of the operation, measured by the number of offspring born within a year. The socio-economic factors of the producer were determined by the level of contribution of profits from the sheep and/or goat enterprise towards the household income. Finally, the psycho-social factors of the producer were analyzed to determine if there is an influence on whether the producer decides to adopt innovations within their operations, and if there is any relation to the status of the operation and/or the socio-economic factors of the producer. The psycho-social factors that will be analyzed are the satisfaction level of the producer towards their operation and the goals they feel are important to the success of their operation.

The use of jargon was avoided when possible; the participants were asked questions related to the functions of their management practices such as record keeping, methods of selecting animals to retain within their herd or flock, as well as feelings regarding the success of their enterprise or challenges they may be experiencing.

Evaluating the Current Knowledge of Small Ruminant Producers on Quantitative Genetic Analysis

The participants were asked to rank their current knowledge of selection indices or estimated breeding values as follows: (1) I know a lot about it, (2) I know some things about it, (3) I have heard of it before, or (4) I have not heard of it before. The term estimated breeding value (EBV) is used to describe a method of genetic evaluation used

when genomic information of an entire population is not available, such as in sheep and goats, as it can be calculated without using genomic data (Christensen & Lund, 2010).

Selection indices have long been used to identify animals in a herd or flock that are more economically-superior than others within a contemporary group (Hazel, 1943). Evaluating livestock using a selection-index is an economically feasible strategy that allows a producer to achieve genetic advancements by improving the net-economic value of a group of animals through selection based on phenotypic measurement versus selection of individual traits (Hazel, 1943). The survey asked producers questions related to these two practices rather than the overall use of quantitative genetic analysis as the terms "selection index" and "estimated breeding value" are more commonly used within the small ruminant industry.

Status of the Operation

Farm status, or status of the operation, was measured using both the purpose of the animal being raised and the farm size. The primary and secondary purposes of the sheep and goats being raised were categorized as meat, milk, fiber, or other. The primary purpose of the animal would be the main reason the producer raises that animal and does not necessarily have to be the most profitable, however, this is where the producer places a majority of their effort in improving genetic traits. The secondary purpose of the animal, if any exists, would be an additional source of revenue that is generated that does not fit the objectives of the primary breeding scheme. Farm size was measured by asking the producers the number of females bred and the number of breeding males used in the 2017 breeding season, and the number of offspring born in 2018. Tey and Brindall (2012)

suggest that larger farms can more readily absorb the risk and financial costs associated with implementing new technologies.

Socio-economic Factors

The socio-economic status of the producer was measured in this model using the annual income of the operation as a measure of farm profitability and portion of farm profit contributed to household income. In the survey questionnaire, producers were asked about the level of profits they receive from the products they produce. The annual income was measured as an ordinal variable on predetermined subscales: (1) $0-20,000, (2) $20,001-40,000, (3) $40,001-60,000, (4) $60,001–80,000, (5) $80,001- 100,000, (6) $100,001 +, and (7) Prefer not to answer.

The portion of farm income contributed to household income was also measured as an ordinal variable. The selection choices of this question were: (1) sole source of income, (2) main source of income, (3) supplemental source of income, and (4) not a source of income. The difference between "sole source of income" and "main source of income" is that the latter receives some, even if nominal, amount of money from a non-sheep nor goat source.

Psycho-social Factors

The psycho-social factors sought to illustrate the level of satisfaction the producer felt towards their sheep or goat operation as well as their goals and objectives. Satisfaction was measured using a five-point Likert-scale from (1) strongly disagree to (5) strongly agree; a sixth option was included for "not sure". It was later discovered that the sixth option for "not sure" was repetitive to "neither agree nor disagree" as both variables elicit a neutral response – responses that were coded for the sixth option were

recoded to option three for the analysis. The five variables used in the measure are as follows: 1. I am satisfied with the profit I receive from my sheep/goat enterprise, 2. I am satisfied with my ability to make decisions regarding my sheep/goat enterprise, 3. I am satisfied raising sheep and/or goats, 4. I am satisfied with the overall health of my herd/flock, and 5. I am satisfied with the support and information resources available to me. Factors related to the satisfaction of the producer were included since Peel, Berry, and Schirmer (2016) identified that the wellbeing of a farmer could predict the likelihood of them leaving the farming occupation. It was also noted that farmers who experienced poorer wellbeing were less profitable farmers, younger farmers, farmers with larger farms, and farmers relying more heavily on the farm to support their household income.

The producer's goals for their operation consisted of five variables measured on a five-point Likert-scale ranging from: (1) strongly disagree, to (5) strongly agree. The producers were asked to rank their thoughts on the importance of the following statements: 1. Improving the profitability of my farm, 2. Decreasing my farm's expenses, 3. Improving animal performance, 4. Producing animals resistant to disease and parasites, and 5. Producing animals that are more desirable at market. The producers were also asked to list any other goals for their operation that were not previously mentioned.

Intent to Adopt Quantitative Genetic Analysis

A small ruminant producers' intent to adopt the use of quantitative genetic analysis was originally measured with four potential responses: "yes", "no", "not sure", and "currently do", however, for the logistic regression analysis the responses were recoded as a dichotomous variable. The response choices of "yes" and "currently do"

were recoded to “yes”, and the response choices “no” and “not sure” were recoded to “no”.

Demographic Information

The remaining items in the questionnaire served to collect demographic data on the small ruminant producers. These questions pertained to the age, sex, and highest level of education of the producer. The age of the producer was measured on an ordinal subscale: 18 – 19 years old, 20 – 29 years old, 30 – 39 years old, etc. A ten-year subscale was utilized to analyze trends or differences between various age groups of producers. The minimum age for participation in the research study was 18 years of age – for organizational purposes the first ordinal subscale represented a smaller age-range of participants compared to the others. Previous literature has found connections between the age of a small ruminant producer and their engagement in specific herd management practices (Poku, 2009). It was discovered that small producers between the ages of 40 and 49 had the highest proportion of written records, while none of the producers between the ages of 50 and 59 had kept any written records on their herd or flocks (Poku, 2009).

It has also been suggested that producers with a higher level of education better comprehended agricultural technologies and were more likely to share information with peers compared to those with lower levels of education (Gowda & Dixit, 2015). The highest level of education of producers was measured on a multiple choice scale with selections of high school degree, some college, associate degree, etc. This type of data aided in explaining some of the variances between other analyzed factors and potential correlations that would help describe the type of small ruminant producer who would be more likely to engage in quantitative genetic analysis strategies.

Validity and Reliability

The survey questions prompted multiple choice, Likert-scale, and open-ended responses. The questions were evaluated for face and construct validity by a panel of experts selected for their professional contributions to the sheep and goat industry. The questionnaire was reviewed initially by the committee members of this study to ensure the items met the overall objectives and the questions elicited fair and unbiased responses. The committee also confirmed the overall flow of the questionnaire and placement of questions to reduce response fatigue from participants. Select members of the sheep and goat industry were also asked to review the instrument and provide feedback from the industry perspective. There were two individuals who fulfilled this request: a Penn State Extension County Livestock Educator, and a member of the Genetic Advancement Committee of the American Dairy Goat Association. The feedback received from these individuals were pertinent to the development of an effective evaluation instrument.

There has not been a research instrument previously developed to measure the objectives established in this study. Therefore, the items that were included in the questionnaire were developed for this purpose. To establish reliability for the instrument, a pilot test was conducted with a small population of producers in the state of Pennsylvania (n = 175) to evaluate the internal consistency of the instrument. The location for the field test was determined based on accessibility and a comparison of factors relative to New York State such as climate, numbers of sheep and goat producers, and marketing preferences.

Pilot Test:

The pilot test was administered on November 5th, 2018 solely through e-mail distribution in a procedure similar to the eventual survey distribution. There was no pre-notification or non-respondent follow-up used for this field test. Of the 175 e-mails that were sent, there were 57 e-mails that bounced due to invalid e-mail addresses or recipient privacy settings that would not permit incoming mail from unknown senders. Since e-mail distribution was the only method of contact used for this pilot test, a follow-up reminder was sent to non-respondents both one-week after the initial distribution and again after two weeks. The data collection period for the field test lasted for a total of three weeks. There were 20 responses collected during this period that were used for further analysis. Excluding the undeliverable e-mail requests, the response rate for this field test was 23.6%.

The scales used to determine the major areas of interest were analyzed for internal consistency using a reliability analysis. The items used to measure the producer goals for their operation formed an internally consistent measure ($\alpha = 0.92$) to evaluate how the producer ranked the importance of common management goals. The items that were used to measure the overall satisfaction of the producer towards their operation had initially yielded a low internal consistency ($\alpha = 0.54$); when two items were removed from this scale (I plan to expand my herd or flock in the next five years and I plan to expand the sheep/goat products that I offer in the next five years) the internal consistency of this measure had improved to an acceptable level ($\alpha = 0.71$). It was determined that the items that were removed would not negatively affect the objective of this measure. The final measures examined by a reliability analysis for internal consistency were the items used

to determine the presence and extent of barriers that may have inhibited the adoption of the management practice; this yielded an acceptable level of internal consistency (α = 0.74). Bland and Altman (1997) report that alpha values of 0.7 to 0.8 are satisfactory, however for the most accurate results an alpha value of 0.95 was desired.

Sources of Error:

According to Fogli and Herkenhoff (2018), there are many sources of errors and biases in survey research that can severely influence the results. However, when these sources are recognized, they can be managed so their occurrence is limited and influences on data can be accounted for. Potential sources of error were recognized during the development of the research methodology and proactive steps to minimize the influence of these errors were taken. Dillman (2000) describes four possible sources of error in survey research: sampling error, coverage error, measurement error, and nonresponse error.

Sampling error occurs when the sample size is not large enough to sufficiently make inferences about an entire population. In this study, a convenience sample of participants was utilized for the accessibility of their contact information. Since a randomized sample of the entire population was not used, the results of this study cannot be generalized to anyone outside of the sample. When the sample size is too small to accurately represent the population, the chances of experiencing a Type II error by incorrectly rejecting the hypothesis is increased.

Coverage error was addressed by using a combination of delivery methods to administer the survey. Although the survey was only administered through e-mail

delivery during the initial data collection period, follow-up attempts with both mailed surveys and phone interviews reduced the chance of participants not having access to the survey.

Measurement errors are often ignored when conducting survey research because it is believed they are not large enough to have a significant effect on the overall results, however Saris and Revilla (2016) proved this statement to be false. Measurement error was addressed by having the survey instrument reviewed for content and face validity by a panel of experts.

Lastly, nonresponse error was addressed by following a data collection protocol that accounted for nonresponse which is discussed further in chapter three. Individuals who did not provide a response during the initial data collection period were followed-up with afterwards. Responses were collected using both mailed surveys and phone interviews and a comparison of early and late respondents was performed.

Comparison of Early and Late Respondents:

Dillman (2000) describes four possible sources of error in survey research: sampling error, coverage error, measurement error, and nonresponse error. Attempts to reduce sampling error, coverage error, and measurement error have been described in chapter three. Nonresponse error suggests that individuals in a sample who do not provide usable responses are characteristically different than those who do (Lindner, Murphy, & Briers, 2001).

To reduce the risk of nonresponse error as a threat to the external validity of this study, data was compared from early and late respondents using an independent sample t-

test. Early respondents were those who provided usable data during the initial data collection time-period while data from late respondents was collected using mailed surveys and phone interviews after the initial data collection time-period had ended.

Early and late respondents were compared on the dependent variable measuring the intent to adopt the use of quantitative genetic analysis strategies within their herd or flock. Levene's test for equality of variances showed no significant difference between the two sub-groups ($\alpha = 0.008$). This confirms that nonresponse error was not a threat to the external validity of this study.

Data Collection Timeline:

Dillman's Tailored Design Method (Dillman, Smith, & Christian, 2014) was utilized for the design and administration of the survey instrument. A pre-notification postcard was sent to individuals one-week prior to the administration of the survey instrument, notifying the individuals of their selection to participate in the research study and when to expect to receive the survey questionnaire. A cover letter detailing the purpose of the research study, the benefits that the results may provide to the livestock producer, and the research consent protocol was attached to the survey questionnaire in the initial administration- see Appendix B: Cover Letter. Two-weeks after the initial attempt, non-respondents were sent a second e-mail request to complete the survey, which once again stressed the importance of receiving their input. Selected participants (n = 149) who did not respond to the initial questionnaire request were mailed a signed cover letter and questionnaire to their physical address along with instructions for submitting their responses. Non-respondents that did not have a listed phone contact

were sent a mail package while others received phone calls to compare data from early and late respondents. Table 3-1 shows the data collection timeline for the study.

Table 3-1: Data Collection Timeline

Type of Contact	Description	Date
Pre-notification Postcard	Postcard sent to all selected participants informing them of their selection to participate in the research study and when to expect to receive the survey questionnaire.	November 26, 2018
Survey Invitation Notice	E-mail sent to all selected participants with information pertaining to the survey, research consent protocol, and link to the Qualtrics survey.	December 3, 2018
Follow-up Reminder	E-mail sent to all non-respondents reminding them of their selection to participate in the research study. Description of research study, consent protocol and link to the survey were also included.	December 17, 2018
Mailed Package	Printed survey and signed cover letter detailing the research study, consent protocol and instructions for return were mailed to select non-respondents.	January 14, 2019
Phone Interview	Select non-respondents were contacted to collect survey data via phone call	January 7 – 21, 2019

Response Rate:

The population for this research study consisted of 981 selected participants. The unknown accuracy of the contact database that was utilized was a risk that was taken and may have an unknown influence on the number of selected participants that were able to respond. It was found that many of the attempted contacts were unsuccessful due to the inaccessibility of the participants. Of the 981 selected participants approximately 10.6% (n = 104) and 41.8% (n = 410) produced undeliverable pre-notification postcards and bounced e-mailed survey requests, respectively. The response rate for this research study was only calculated for the number of individuals who received an e-mailed survey request (n = 571) and was found to be 9.5% (n = 54). Baruch and Holtom (2008) indicated that an average response rate for a survey collecting information from individuals was 52.7%. Non-respondents were contacted to bring the total number of usable responses to 77. Table 3-2 illustrates the response summary for this study.

Table 3-2: Response Summary

Event	n	%
Pre-notification Cards Sent	981	-
Pre-notification Cards Undeliverable	104	10.6
E-mail Survey Requests Sent	981	-
E-mail Survey Requests Bounced	410	41.8
Initial Response Rate	**54**	**9.5***
Mailed Surveys Sent	149	-
Mailed Survey Responses Received	7	4.7
Phone Interview Responses	16	-
Overall Response Rate	**77**	**13.5***

*Response rates were calculated using the number of subjects who successfully received a survey questionnaire (n = 571).

Data Analysis:

The data for this research study was analyzed using IBM SPSS Statistics 25. Frequency and descriptive statistics were analyzed to portray an image of the small ruminant producers who participated in the study. The use of these statistics allowed for an evaluation of various factors that may contribute to a producers' decision to utilize quantitative genetic analysis within their herds or flocks. In addition, index values were developed for the independent variables measured on Likert-scales. Indices were created by using the mean scores for the measures of goals for operation (goals), satisfaction towards the operation (satisfaction), and barriers to adoption (barriers). Throughout the survey there were questions that respondents chose not to provide responses to – this missing data is excluded from the analysis for the objectives it applies to.

A binary logistic regression analysis was performed to evaluate the factors influencing a small ruminant producers' decision to adopt quantitative genetic analysis strategies. There were six factors included in this analysis: number of offspring born (herd size), contribution of farm income to household (income), goals, satisfaction, barriers, and age of producer. The dependent variable being tested was the small ruminant producers' intent to adopt quantitative genetic analysis. There were six independent variables used in this regression model: number of offspring born, satisfaction, barriers, categorized household income, goals, and age. The scales that measured satisfaction, barriers, and goals were composed of multiple Likert-type questions that were converted to an index value using the mean score for each scale. Since mean scores were used, these new indices that were developed were measured on a continuous scale. The variables for number of offspring born and age were also measured

on a continuous scale. Dummy variables were created for the variable of categorized household income to allow for interpretation of each categorical level within the regression analysis.

There were other variables that were identified for use in the model, as described in previous sections. However, due to the low number of usable responses received from the survey questionnaire, the reliability of the model to accurately predict the intent to adopt the practice was questionable. Chao-Ying, Kuk, and Ingersoll (2002) have concluded from the existing literature that the recommended minimum sample size for a logistic regression analysis is 100, plus an additional 50 subjects for each predictor variable used. For that reason, the number of predictor variables used in the model was reduced to six variables that were selected for their perceived usefulness as gathered from the literature.

Limitations:

There were several limitations that may have influenced the results of the study. The accuracy of the contact database that was utilized for this study may have been questionable. The database was developed through a compilation of contacts of individuals who have either participated in a Cornell Sheep and Goat Program in the past or have expressed an interest in staying up to date on news and events. Some of the individuals in the database may have changed email or physical address, stopped producing sheep or goats, or deceased. This may have negatively influenced the number of usable responses received.

Another limitation of the study is the non-randomized population sample that was utilized. Since a random sampling technique was not utilized, it may be possible that the small ruminant producers who were included may have been characteristically different due to their previous interactions with the Cornell Sheep and Goat Program.

The low response rate of the survey further limits the generalizability of the findings and conclusions can only be drawn regarding the population being tested. While a target survey response rate has traditionally been 80%, growing literature has observed a lack of correlation between low response rates and nonresponse bias (Hendra & Hill, 2018). The small sample size used in the statistical analysis may have reduced the accuracy of the binary logistic regression, as a minimum sample size of 100 subjects is recommended (Chao-Ying, Kuk, & Ingersoll, 2002). Due to the small sample size, the statistical power of the model is decreased and the possibility of conducting a type II error of incorrectly accepting the null hypothesis is increased. To reduce the risk of conducting a type II error, the number of variables used in the regression was restricted to six variables. These limitations restrict the findings of this study and therefore the results cannot be generalized to all sheep and goat producers. However, the results of this study can be used to generate important dialogue on the subject and serve as a framework for additional research opportunities.

Summary of Procedures:

The population for this survey consisted of sheep and goat producers in New York State. A convenience sample of this population (n = 981) was utilized based on the availability of accessible contact information. The survey yielded an initial response rate

of 9.5 percent (n = 54), however, after following up with nonrespondents a total of 77 usable responses were collected (13.5%).

Descriptive research methods were used to conduct this study. Data was collected through a survey questionnaire administered through Qualtrics® and distributed through an email link. The survey instrument was reviewed for content and face validity by a panel of experts selected for their professional contributions to the small ruminant industry. To evaluate the reliability of the instrument, a pilot test was conducted. There were 175 sheep and goat producers from the state of Pennsylvania invited to complete the pilot survey. After minor adjustments were made, the survey was found to have acceptable reliability on each of its constructs.

The survey questionnaire identified three major areas of concern: (1) status of operation, (2) socio-economic status of the producer, and (3) the effects of psycho-social factors in influencing a producers' decision to adopt the use of quantitative genetic analysis within their herds or flocks. To answer the research questions of this study, descriptive statistics were evaluated for each of the objectives and a binary logistic regression was performed to evaluate the use of predictor variables to measure the intent of a small ruminant producer to adopt the use of quantitative genetic analysis strategies.

Chapter 4

The contents of this chapter provide a summary of the purpose and objectives of the study, a summary of procedures, and the results of the research study.

Purpose and Objectives:

The purpose of this study was to evaluate the perceptions of sheep and goat producers' in New York State on the adoption of quantitative genetic evaluation as a management tool within their herds or flocks.

This research study is guided by the following objectives:

1. Describe the farm status of small ruminant producers in New York State.
2. Describe the socio-economic factors of small ruminant producers in New York State.
3. Describe the psycho-social factors of small ruminant producers in New York State.
4. Identify barriers that may inhibit the adoption of quantitative genetic analysis strategies for small ruminant producers.
5. Evaluate the influence of farm status, socio-economic factors, psycho-social factors, and barriers as predictors for the adoption of quantitative genetic analysis strategies for small ruminant producers

This research utilized a descriptive survey methodology and evaluation of quantitative data to answer these questions.

Summary of Procedures:

The population for this survey consisted of sheep and goat producers in New York State. A convenience sample of this population (n = 981) was utilized and yielded an initial response rate of 9.5 percent (n = 54), however, after following up with nonrespondents a total of 77 usable responses were collected (13.5%).

Descriptive research methods were used to conduct this study. The survey instrument was reviewed by a panel of experts and a pilot test was conducted in Pennsylvania to evaluate the reliability of the instrument. After minor adjustments were made, the survey was found to have acceptable reliability on each of its constructs.

The survey questionnaire identified three major areas of concern: (1) status of operation, (2) socio-economic status of the producer, and (3) the effects of psycho-social factors in influencing a producers' decision to adopt the use of quantitative genetic analysis within their herds or flocks. Descriptive statistics were evaluated for each of the objectives and a binary logistic regression was performed to evaluate the use of predictor variables to measure the intent of a small ruminant producer to adopt the use of quantitative genetic analysis strategies.

Demographic Information:

Table 4-1 shows the demographic information of the 77 sheep and goat producers that responded to the survey. Some participants opted not to include this information in their responses – this data is not included. It was found that 32.5% of the participants were male and 58.4% were female. The ages of the participants ranged from 19 – 86 years of age; for organization purposes, the table displays the ages in ten-year subscales

with frequencies and percentages. Subscales with no available data were omitted from the table. The minimum age for participation was 18 years old.

The highest level of education of the surveyed sheep and goat producers is reported in table 4-2. There were 9.1% of participants that had completed a high school degree, 19.5% of participants had completed some college, 11.7% of participants completed an associate degree, 26% of participants completed a bachelor's degree, 13% of participants completed a master's degree, and 11.7% of participants completed a doctoral degree.

Table 4-1: Age and Gender Information of Sheep and Goat Participants (n = 70)

Variable	n	%
Gender		
Male	25	35.7
Female	45	64.3
Total	70	100.0
Age		
18-19	2	2.9
20-29	4	5.9
30-39	4	5.9
40-49	10	14.7
50-59	23	33.8
60-69	12	17.6
70-79	10	14.7
80-89	3	4.4
Total	68	100.0

Table 4-2: Highest Level of Education of Sheep and Goat Participants (n = 70)

Variable	n	%
Highest Level of Education		
High School	7	10.0
Some College	15	21.4
Associate Degree	9	12.9
Bachelor's Degree	20	28.6
Master's Degree	10	14.3
Doctoral Degree	9	12.9
Total	70	100.0

Evaluating New York Sheep and Goat Producers' Current Knowledge of Quantitative Genetic Analysis and Anticipated Use:

To gain an understanding of the present knowledge of quantitative genetic analysis within the population of New York State, participants were asked to rank their current knowledge of performance indices or estimated breeding values.

There were 5.2% of participants that indicated they know a lot about these tools, while 40.3% of participants indicated they know some things about it, 22.1% of participants had heard of it before, and 24.7% of participants have not heard of these tools. Table 4-3 illustrates the distribution of producer's current knowledge of selection indices and estimated breeding values.

Of the responding participants of this population, there were 5.2% of sheep and goat producers that were currently using selection indices or estimated breeding values in their herd or flocks. There were 19.5% of participants that had indicated they have considered using these tools, while 53.2% of participants indicated they have not considered using these tools, and 14.3% of participants were not sure if they have

considered using these tools. The distribution of the use of estimated breeding values amongst these sheep and goat producers is also displayed in table 4-3.

Table 4-3: Distribution summary of sheep and goat producers' current knowledge and anticipated use of selection indices and estimates breeding values within their herds and flocks.

Variable	n	%
Producer Knowledge		
I know a lot about it	4	5.6
I know some things about it	31	43.7
I have heard of it before	17	23.9
I have not heard of it before	19	26.8
Total	71	100.0
Anticipated Use		
I currently use these tools	4	5.6
I have considered using these tools	15	21.1
I have not considered using these	41	57.7
Not sure	11	15.5
Total	71	100.0

Objective 1: Describe the Farm Status of Small Ruminant Producers in New York State

The farm status of the operation was measured using the primary and secondary purposes of the animals being raised in addition to the average herd or flock size. These variables were analyzed independently for both sheep producers and goat producers. It was found that the largest percentage of sheep producers were raising sheep primarily for meat production. Fiber production was the most frequent secondary purpose of raising sheep. Similar to sheep, the largest percentage of goats were raised primarily for meat production. The "other" option was also frequently selected (18.2%) as a primary purpose

for raising goats – qualitative responses provided as text-entries on the survey questionnaire revealed that vegetation control and recreational uses were common reasons for raising goats. The most frequent secondary purpose for raising goats was found to also be meat production. The frequency statistics for this data are reported in table 4-4.

Table 4-4: Summary of Primary and Secondary Purposes of Sheep and Goats.

Variable	Primary Purpose		Secondary Purpose	
	n	%	n	%
Sheep				
Meat	27	35.1	6	7.8
Milk	2	2.6	0	-
Fiber	8	10.4	16	20.8
Other	1	1.3	4	5.2
Total*	38	49.4	26	33.8
Goat				
Meat	23	29.9	16	20.8
Milk	12	15.6	5	6.5
Fiber	1	1.3	1	1.3
Other	14	18.2	12	15.6
Total*	50	64.9	34	44.2

*Total numbers may differ from total number of producers as some operations include both sheep and goats.

Farm size was also used as a measure of the status of an operation. Information was collected regarding the number of females bred in 2017, the number of breeding males used in 2017, and the number of offspring born in 2018. The median numbers were used to interpret these results. The median number of females bred on sheep operations was almost triple compared to the goat operations and the number of offspring born was double. There was only a minor difference in the number of breeding males

used on sheep farms compared to goat farms. It should be noted that some farms did not breed their sheep or goats as part of their farm objective, so the minimum numbers for both sheep and goats were zero. Table 4-5 illustrates the distribution of farm sizes as reported.

Table 4-5: Summary of Farm Sizes of Surveyed Sheep and Goat Producers

Variable	Sheep			Goats		
	Median	Min.	Max.	Median	Min.	Max.
Number of females bred	31.0	0	61.26	12.0	0	130.0
Number of males used	2.0	0	12.0	2.0	0	8.0
Number of offspring born	44.0	0	400.0	22.0	0	189.0

Objective 2: Describe the Socio-economic Factors of Small Ruminant Producers in New York State

The socio-economic status of the producer was measured using the annual income of the operation as a measure of farm profitability and portion of farm profit contributed to household income. There was not a large difference in the number of sheep producers (20.8%) compared to goat producers (18.2%) that had indicated their sheep or goat operation was part of a larger diversified farm business. Goat producers had most frequently categorized farm profits from their goat operation as "not a source of income" (28.6%), while 24.7% of goat producers categorized farm profits from goat operation as a "supplemental income". Sheep producers had most frequently categorized farm profits as "supplemental household income" (29.9%), while 14.3% of producers categorized farm

profits from sheep operation as “not a source of income”. This data is illustrated in table 4-6.

Table 4-6: Summary of profits generated through sheep and/or goat operations.

Variable	Sheep		Goat	
	n	%	n	%
Categorized Income				
Sole household income	0	-	1	1.3
Main household income	2	2.6	4	5.2
Supp. household income	23	29.9	19	24.7
Not a source of income	11	14.3	22	28.6
Total	36	46.8	46	59.7

Objective 3: Describe the Psycho-social factors of Small Ruminant Producers in New York State

The results revealed that the producers agreed with three of the variables as indicated by a mean statistic greater than 4.0. These variables were “I am satisfied with my ability to make decisions regarding my sheep/goat enterprise”, “I am satisfied raising sheep and/or goats”, and “I am satisfied with the overall health of my herd/flock”. The producers’ neither agreed nor disagreed with two variables: “I am satisfied with the profit I receive from my sheep/goat enterprise” and “I am satisfied with the support and information resources available to me”. The distribution summary for this measure is illustrated in table 4-7.

Table 4-7: Sheep and goat producer's feelings of satisfaction towards their operation.

Variable	M	SD
I am satisfied with…		
Profit I receive from enterprise	3.04	1.18
Ability to make decisions regarding enterprise	4.27	0.98
Raising sheep and/or goats	4.66	0.74
Overall health of herd or flock	4.25	0.92
Support and information resources available	3.65	1.12

The producer's goals for their operation consisted of five variables measured on a five-point Likert-scale ranging from: (1) strongly disagree, to (5) strongly agree. The producers were asked to rank their thoughts on the importance of statements regarding the management objectives of their operations. The mean statistics showed that sheep and goat producers were in overall agreement with the goals of improving profitability, decreasing expenses, improving animal performance, producing animals more resistant to disease, and producing animals more desirable at market. Table 4-8 illustrates the distribution of this measure.

Table 4-8: Summary of Sheep and Goat Producers' thoughts on the importance of five goals for improving their current management system (n = 70).

Variable	M	SD
Improving the profitability of my farm	4.29	1.06
Decreasing my farm's expenses	4.11	1.07
Improving animal performance	4.23	1.02
Producing animal's resistant to disease and parasites	4.38	0.97
Producing animals that are more desirable at market	4.04	1.26

Objective 4: Barriers to Implementing Quantitative Genetic Analysis Strategies as a Management Tool in Sheep Flocks and Goat Herds

The survey questionnaire had asked the sheep and goat producers to rank their thoughts on barriers they feel may be preventing them from making record-based breeding decisions on a five-point Likert-scale from (1) strongly disagree to (5) strongly agree. The overall mean statistics revealed that the producers had somewhat disagreed with three of the variables as indicated by a mean statistic of 2.0 – 2.9. The three variables were labor cost associated with record keeping, management style does not allow for regular handling, and knowledge of how to use records. The results revealed that the producers did not agree nor disagree with two of the variables as indicated by a mean statistics of 3.0 – 3.9. These variables were time able to spend on sheep/goat enterprise and ability to obtain information for records. The distribution summary for this measure is illustrated in table 4-9.

Table 4-9: Perceived barriers towards making record-based management decisions.

Variable	M	SD
Perceived barrier		
Time able to spend on enterprise	3.43	1.27
Labor cost associated with record keeping	2.91	1.14
Ability to obtain information for records	3.06	1.29
Management style does not allow for regular handling	2.65	1.49
Knowledge of how to use records	2.88	1.36

Objective 5: Evaluate the Influence of Farm Status, Socio-economic Factors, and Psycho-social Factors as Predictors for the Adoption of Quantitative Genetic Analysis Strategies for Small Ruminant Producers.

A binary logistic regression was used to determine the influence of farm status, socio-economic factors, psycho-social factors, and barriers as predictors for the adoption of quantitative genetic analysis. The dependent variable tested was the small ruminant producers' intent to adopt quantitative genetic analysis which was measured on a dichotomous scale. There were six independent variables used in this regression model: number of offspring born, satisfaction, barriers, categorized household income, goals, and age.

The assumptions of the binary logistic regression were tested and satisfied. The dependent variable of "intent to adopt quantitative genetic analysis" was measured on a dichotomous scale using *yes* and *no*. There were six independent variables used, both categorical and continuous. There was no relationship between the independent variables that was created during the design process. The variables were free of multicollinearity as indicated by a Variance Inflation Factor (VIF) of less than five for all of the predictors.

The binary logistic regression revealed the six independent variables used in the model were not significant predictors of a small ruminant producer's intent to adopt the practice of quantitative genetic analysis. Overall, the model explains 11.7 percent of the variance in the predictor values for the adoption of quantitative genetic analysis strategies as indicated by the Nagelkerke R square coefficient. The model accurately predicted 97.7 percent of cases where the decision to adopt the innovative practice was not achieved, leading to an overall correct prediction rate of 71.7 percent. The goodness of fit for the

model revealed a 5.04% likelihood that the predictor variables were not a significant indicator of a small ruminant producers' intent to adopt quantitative genetic analysis Test [Chi-square = 5.04, df = 8, $\alpha = 0.754$ ($\alpha > 0.05$)]. The Hosmer and Lemeshow Test calculates if the observed event rates matches the expected event rates in the subscale categories; this test did not yield a significant result [Chi-square = 6.62, df = 8, $\alpha = 0.579$ ($\alpha > 0.05$)], which suggests that the data was not properly fit for the model. Since none of the predictors in the model yielded a significant Wald statistic result, it can be concluded that the variables used did not contribute significantly to predicting the producer's intent to utilize quantitative genetic analysis in their herd or flock management systems. The results of the binary logistic regression can be seen in table 4-10.

*Table 4-10: Results of binary logistic regression (predictor variables*intent to adopt quantitative genetic analysis)*

	B	S.E.	Wald	df	p	Exp(B)
Constant	-1.722	3.127	0.303	1	0.582	0.179
Number Offspring	-0.095	0.004	0.226	1	0.634	0.998
Satisfaction	0.095	0.540	0.031	1	0.860	1.100
Barriers	0.173	0.433	0.160	1	0.689	1.189
Goals	0.348	0.422	0.680	1	0.410	1.416
Age	0.024	0.022	1.103	1	0.294	1.024
Not a Source of Income*	-	-	3.051	3	0.384	-
Supplemental Source of Income*	19.819	40192.97	0.000	1	1.000	$4.0x10^8$
Main Source of Income*	-0.273	1.534	0.032	1	0.859	0.761
Sole Source of Income*	-1.279	0.776	2.717	1	0.099	0.278

Note: Intent to adopt quantitative genetic analysis coded as 1 for *yes* and 2 for *no*.

*Dummy variables were created for the variable of "categorized income" to measure each category independently within the regression analysis.

Crosstabulations were performed to determine which, if any, of the predictor variables used in the model are correlated to the small ruminant producer's intent to adopt the use of quantitative genetic analysis. None of the variables used in the analysis revealed a significant relationship with the intent to adopt the practice of quantitative genetic analysis. There was one variable that was approaching significance ("I am satisfied with the profit I receive from my sheep/goat operation" [Chi-Square = 20.576, df = 12, $\alpha = 0.057$ ($\alpha > 0.05$)]. The complete findings of the crosstabulation analysis are reported in table 4-11.

*Table 4-11: Crosstabulation table (individual predictor variables*intent to adopt quantitative genetic analysis)*

Variable	Chi-Square	df	Sig.
Satisfaction			
Profit received	20.58	12	0.06
Decision latitude	18.55	12	0.10
Raising sheep/goats	9.93	9	0.36
Health of herd/flock	14.37	9	0.11
Support resources	12.32	12	0.42
Goals			
Improving profit	6.64	12	0.88
Decreasing expenses	14.62	12	0.26
Improving animal performance	11.67	12	0.47
Producing animals resistant to disease	7.30	12	0.84
Producing animals more desirable at market	6.96	12	0.86
Barriers			
Time	16.98	12	0.15
Labor	8.76	12	0.72
Ability to obtain records	11.62	12	0.48
Management style	12.08	12	0.44
Knowledge	11.52	12	0.49
Categorized household income	9.46	9	0.40

Summary of Results:

While the independent variables identified for the logistic regression were not accurate predictors of a small ruminant producers' intent to adopt the use of quantitative genetic analysis, the descriptive results of the study still provide value to researchers in the field.

The demographic data of the small ruminant producers in this study revealed that a majority of the surveyed producers were female (58.4%). It was also discovered that while the age of the producer widely varied, the most frequent age of producer was found to be 50 to 59 years old (29.9%). A majority of the surveyed producers held at least a high school or college degree, with the most frequent highest level of education being a bachelor's degree (26%). Participants had most frequently indicated that they knew some things about quantitative genetic analysis (40.3%), however the majority had not considered using the innovative tool (53.2%). There were only four respondents (5.2%) that indicated they were currently using a method of quantitative genetic analysis in their herd or flock.

On average, sheep producers raised almost double the number of animals per year compared to goat producers. Sheep producers were also found to place a higher emphasis on the profitability of their enterprise, contributing more of the profits from their farms towards their household income compared to goat producers. Further research may be needed to determine if sheep producers are more progressive than goat producers.

Chapter 5

The contents of this chapter provide a summary of the purpose and objectives of the study, a discussion of findings, conclusions, and implications, and recommendations for future research.

Purpose and Objectives:

The purpose of this study was to evaluate the perceptions of sheep and goat producers' in New York State on the adoption of quantitative genetic evaluation as a management tool within their herds or flocks.

This research study is guided by the following objectives:

1. Describe the farm status of small ruminant producers in New York State.
2. Describe the socio-economic factors of small ruminant producers in New York State.
3. Describe the psycho-social factors of small ruminant producers in New York State.
4. Identify barriers that may inhibit the adoption of quantitative genetic analysis strategies for small ruminant producers.
5. Evaluate the influence of farm status, socio-economic factors, psycho-social factors, and barriers as predictors for the adoption of quantitative genetic analysis strategies for small ruminant producers

This research utilized a descriptive survey methodology and evaluation of quantitative data to answer these questions.

Summary of Procedures:

The population for this survey consisted of sheep and goat producers in New York State. A convenience sample of this population (n = 981) was utilized based on the availability of accessible contact information. The survey yielded an initial response rate of 9.5 percent (n = 54), however, after following up with nonrespondents a total of 77 usable responses were collected.

Descriptive research methods were used to conduct this study. Data was collected through a survey questionnaire administered through Qualtrics and distributed through an email link. The survey instrument was reviewed for content and face validity by a panel of experts selected for their professional contributions to the small ruminant industry. To evaluate the reliability of the instrument, a pilot test was conducted. 175 sheep and goat producers from the state of Pennsylvania were invited to complete the pilot survey. After minor adjustments were made, the survey was found to have acceptable reliability on each of its constructs.

The survey questionnaire identified three major areas of concern: (1) status of operation, (2) socio-economic status of the producer, and (3) the effects of psycho-social factors in influencing a producers' decision to adopt the use of quantitative genetic analysis within their herds or flocks. To answer the research questions of this study, descriptive statistics were evaluated for each of the objectives and a binary logistic regression was performed to evaluate the use of predictor variables to measure the intent of a small ruminant producer to adopt the use of quantitative genetic analysis strategies.

Findings, Conclusions, and Implications:

A summary and discussion of the research findings for each objective are found below. The findings of this study serve to provide insight into the decision-making behaviors of small ruminant producers and identify the barriers to adopting the practice of quantitative genetic analysis. The findings also recognize the need for future research and generates awareness of this innovative management tool.

Overall, it was found that of the small ruminant producers in the survey, the majority were female (58.4%). The most frequent age group of the respondents was 50-59 years of age (29.9%). Most of the survey respondents held at least a high school or college degree, with the most common highest education level being a bachelor's degree (26%). Participants had most frequently indicated that they knew some things about quantitative genetic analysis (40.3%), however the majority had not considered using the innovative tool (53.2%). There were only four respondents (5.2%) that indicated they were currently using a method of quantitative genetic analysis in their herd or flock.

Objective 1: Describe the Farm Status of Small Ruminant Producers in New York State.

The farm status was found to vary drastically across the sheep and goat farms in New York State. The major differences in herd and flock sizes may represent the diverse uses for small ruminants. The first objective of the study was to describe the current farm status of small ruminant enterprises in New York state. The primary and secondary purposes of the sheep and goats being raised on the surveyed farms was analyzed. For sheep producers, the primary purpose for raising sheep was for the production of meat (n = 27, 35.1%). The largest secondary purpose of the sheep being raised was fiber production (n = 16, 20.8%). For goat producers, the primary purpose for

raising goats was for meat production (n = 23, 29.9%). The "other" choice was also selected frequently for primary purpose of raising goats (n = 14, 18.2%) – text entry responses for "other" included goats for brush control, goats for packing, and goats for other leisure purposes. The largest secondary purpose for raising goats was also for meat production (n = 16, 20.8%). This repetition may be due to the fact that excess dairy bucks or goats unable to effectively satisfy their primary purpose are often sold for human consumption. The primary and secondary purposes of the animals being raised revealed that while meat production may be the leading industry for both sheep and goats, producers have also developed niche uses for their animals that are not often seen in other livestock. There was a large emphasis on the use of sheep and goats for vegetation control and recreational purposes. This finding may support the idea that small ruminant producers are characteristically different than other livestock producers.

The size of an operation was also used to describe the farm status of small ruminant producers. On average, sheep producers raised almost double the number of offspring than goat producers. The average number of lambs born on an operation in 2018 was 82.6 lambs, while goat producers raised an average of 42.6 kids. Cappai, et. al. (2014) suggested that while larger farms may begin to see the benefits of improved management systems faster than small farms, the frequency in obtaining information for records is reduced due to increased labor requirements. These figures may indicate that differences in herd and flock sizes may influence the decision to invest in innovative technologies amongst sheep and goat farms.

Objective 2: Describe the Socio-economic Factors of Small Ruminant Producers in New York State.

The socio-economic behaviors of small ruminant producers were determined through a summary of profits generated through the sheep and/or goat operation. In the survey questionnaire, producers were asked about the level of profits they receive from the products they produce. Due to the very low number of responses on this measure, this data was removed from the analysis.

It was determined that the contribution of the profits received from the sheep and/or goat enterprise towards the household income was of more significance to the scope of this study. Moore, et. al. (1991) had found that farmers who sell their livestock as a main source of their household income had placed a greater emphasis on the overall health and productivity of their livestock. It was also determined that the contribution of outside household income may financially support the use of new practices, however, the tradeoff is that there is less labor available when family members hold jobs outside of the farm.

The study revealed that sheep producers placed a higher priority on farm profitability as the sheep producers had most frequently categorized the profits from their sheep enterprise as a "supplemental household income" (29.9%) compared to the goat producers who most frequently categorized farm profits as "not a source of income" (28.6%). Since sheep producers also produced almost double the number of offspring in 2018 compared to goat producers, it may indicate that the sheep industry in New York State is geared more towards commercial operation. This indication may also be supported by the large number of goat producers who had ranked recreational uses of

goats as their primary purpose. These results are complimentary to the findings of the previous objective; since sheep producers placed a greater emphasis on the contribution of profits towards their household income, they also had larger flock sizes.

Objective 3: Describe the Psycho-social Factors of Small Ruminant Producers in New York State.

The survey had asked the small ruminant producers to rank their satisfaction towards the items listed on a Likert-type scale from (1) strongly disagree to (5) strongly agree. This was important as Saxby, Gkartzios, and Scott (2017) reported that farmers who are not satisfied with their work are less likely to adopt innovations. The sheep and goat producers had rated three of the items on the scale as "somewhat agree". Those items were satisfaction with their ability to make decisions regarding their operation, satisfied raising sheep and/or goats, and satisfaction with overall herd health. The sheep and goat producers were neutral on their satisfaction level with the profit they received from their operation and the number of information and support resources available to them. Ritter, et. al. (2019) found that the amount of information the farmer received from their veterinarian regarding a recommended practice was poorly associated with their intent to adopt the practice. The neutral rating for the item of "I am satisfied with the profit I receive" is complimentary to the previous finding that both sheep and goat producers placed an overall low emphasis on contribution of sheep and/or goat profits towards household income.

It has been previously found that the goals and objectives established by farm owners can be used to accurately predict behaviors and intent to adopt innovative practices (Bergevoet, et.al., 1995). Small ruminant producers were asked to rank the

importance of specific goals towards their operation. The sheep and goat producers were in overall agreeance on all five items as indicated by a mean score of $4 < X > 5$ (somewhat agree). These results are not in harmony with Cary and Holmes (1982), who found that goals related to maximizing profit were placed as a higher priority compared to goals related to personal satisfaction. However, this may be a unique attribute to the small ruminant producers in this study.

Objective 4: Identify Barriers that may Inhibit the Adoption of Quantitative Genetic Analysis strategies for Small Ruminant Producers.

This objective was evaluated by asking sheep and goat producers to rank their perceptions of specific barriers that may inhibit them from making record-based management decisions. The term "record-based management decision" was used in place of quantitative genetic analysis to avoid confusion or nonresponse when completing the survey. It was found that the producers had low perceptions towards the listed barriers.

The small ruminant producers disagreed with the perceived barriers of labor cost associated with record keeping, management style does not allow for regular animal handling, and knowledge of how to use records. This finding is aligned with Bergevoet et al (1995) who found that the intent to achieve the image of a modern farm was influenced more by non-economic goals such as enjoying work and producing a safe product compared to the economic goal of achieving maximum profit. This finding was also of interest due to the overall small herd and flock sizes; however, regular handling may not have been required in their current management system and this variable was not applicable to the producer. This conclusion may be supported by Cappai et al (2014) who found that the frequency of obtaining records is reduced when farm size increases due to

additional labor requirements. The producers did not agree nor disagree on the perceived barriers of time able to spend on operation and ability to obtain records. The results of this measure can either be interpreted as the items listed as perceived barriers were not in fact inhibiting the ability for making record-based management decisions, or since a majority of the surveyed producers did not have an intent to utilize quantitative genetic analysis (73.2%) the perceived barriers just were not applicable to them.

Objective 5: Evaluate the Influence of Farm Status, Socio-economic Factors, Psycho-social Factors, and Barriers as Predictors for the Adoption of Quantitative Genetic Analysis Strategies for Small Ruminant Producers.

It was found that the dependent variables used in the binary logistic regression were not significant predictors of a small ruminant producers' decision to adopt the use of quantitative genetic analysis as proposed in the conceptual framework (figure 2-2). While the predictors used were selected for their significance in findings from other previous literature, there may have been multiple reasons why similar results were not obtained from this model. The factors contributing to farm status, socio-economic factors, psycho-social factors, and barriers may have produced more significant findings if they were viewed more comprehensively in individual studies. The support of previous literature did not exist to assume that these variables may work collaboratively in a model. The variables used in the model may have also been more accurate if the number of responses had increased to contribute more usable data to the analysis. The minimum recommended sample size for a binary logistic regression is 100, with an additional 50 subjects for each additional predictor variable used in the model (Chao-Ying, Kuk & Ingersoll, 2002).

Crosstabulations were performed to further analyze the relationship with each predictor variable with the intent to adopt quantitative genetic analysis. There were no significant relationships that existed for any of the predictor variables identified for use in this study. Due to the consistent insignificant correlations, it may be suggested that the items used to represent the larger constructs were not significantly correlated with the intent to adopt quantitative genetic analysis. However, these items may have been more effectively used to describe the adoption of other innovations.

Summary of Conclusions:

The findings of this study serve to provide insight into the decision-making behaviors of small ruminant producers in adopting innovative management tools. The majority of the surveyed producers were female (58.4%), held a bachelor's degree (26%), and were 50 to 59 years of age (29.9%).

It was found that the majority of surveyed producers had some knowledge of quantitative genetic analysis, as indicated by 40.3% of respondents. There were only four producers (5.7%) who were currently utilizing quantitative genetic analysis in their herd or flock, however, 53% of the respondents reported that they have not considered using this tool.

For both sheep and goat producers, the primary purpose of production was raising animals for meat. While the most common secondary purpose of sheep producers was fiber production, for goat producers it was also meat production. The average size of sheep flocks were almost double that of goat herds – this was found for both the number of breeding females and number of offspring. It was also found that sheep producers had

relied more heavily on the profits generated through their operation to support their household income, compared to goat producers who most frequently ranked the profits of their operation as “not a source of income”.

The small ruminant producers surveyed were somewhat satisfied with raising sheep and/or goats, the overall health of their herd or flock, and their ability to make decisions regarding their operation. The producers had neither agreed nor disagreed on their satisfaction with the profit they receive from their operation and the availability of educational and support resources. The producers had somewhat agreed on all five statements regarding the goals of their operations: (1) improving farm profitability, (2) decreasing farm expenses, (3) improving animal performance, (4) producing animals more resistant to disease and parasites, and (5) producing animals more desirable at market.

The small ruminant producers had somewhat disagreed with the barriers of labor cost associated with records, management style does not allow for regular handling, and knowledge of how to use records. The producers had neither agreed nor disagreed with the barriers of time able to spend on operation, and the ability to obtain information as inhibiting their adoption of quantitative genetic analysis tools.

Lastly, the binary logistic regression did not indicate a significant relationship between the predictors used and a small ruminant producers’ intent to adopt the use of quantitative genetic analysis. Crosstabulation results had also indicated no significant correlations between the individual predictors and the intent to adopt quantitative genetic analysis.

The proposed conceptual model (figure 2-2) was developed using previous literature of agriculture and human behavior. It was proposed that the constructs of farm status, socio-economic factors, and psycho-social factors could be used as a precedent to the Theory of Planned Behavior (Azjen, 1991) to more accurately predict a small ruminant producers' decision to adopt the use of quantitative genetic analysis. Previous studies on the Theory of Planned Behavior had found that sheep producers were heavily influenced by external factors, including goals and structure of the enterprise, which may have influenced their behavioral changes outside the realm of the Theory of Planned Behavior (Elliot, Sneddon, Lee, & Blache, 2011). Findings from the current study revealed similar challenges to those of Gilbert and Rushton (2016) in that using the Theory of Planned behavior to measure the behavioral intentions of farmers has a trade-off between including enough constructs to support a strong explanatory power and creating a survey instrument that does not promote participant attrition. The diverse constructs that were included in the model were independently supported by previous literature, however, the interaction of the constructs did not produce significant results. While the use of the predictor variables did not lead to novel findings, it served to provide further insight into the innovation-adoption behaviors of sheep and goat producers. The constructs that were identified had also provided a unique survey of the small ruminant industry in New York State.

Recommendations for Small Ruminant Producers:

With the increasing growth of the sheep and goat industry in the United States, producers should strive to increase the economic performance of their herds or flocks. The utilization of innovative strategies such as quantitative genetic analysis highlights

pertinent information relevant to livestock performance and health. Of the surveyed producers, only 5.2% indicated that they were currently engaged in this practice. There were 40.3% of participants who indicated that they had some knowledge of the technology but did not engage in the practice. Stronger efforts are required to increase awareness of the potential values of this practice and to assist producers in adopting the technology. As previously mentioned, Cooperative Extension Educators are an invaluable resource in fulfilling this task and should be better utilized.

Producers should also take advantage of the many educational opportunities that already exist. Extension provides workshops and seminars on a multitude of animal health and profitability topics. These experiences have evolved to accommodate wider audiences and have been expanded to provide remote access to anyone in the world. Program participation is a major consideration when evaluating the effects of these programs and attendance may be a deciding factor on whether a program will continue. Besides providing an opportunity to increase subject knowledge, producers could also utilize these experiences to network with fellow producers, develop personal relationships with Extension professionals, and realize that many others share similar challenges to the ones they do. There were only 36.2% of producers who indicated that they had attended an educational class, seminar, or workshop on quantitative genetic analysis strategies in the past. On the contrary, there were 71% of participants who indicated that they plan to attend an educational class, seminar, or workshop on quantitative genetic analysis strategies in the future. Increased adoption of this innovative practice will not only assist producers in improving their own herds or flocks but also

contribute valuable data to national databases which will in return increase the overall accuracy of breed-wide index values.

In summary:

1. Producers should place a higher emphasis on increasing the economic efficiency of their herds or flocks to remain viable in a competitive market environment.
2. Producers should take advantage of more educational opportunities.

Recommendations for Extension Educators:

Extension educators assist in the dissemination of research throughout communities. It is important for educators to properly identify the needs of the community clientele so that relevant and effective solutions can be implemented. With the increased availability of technological resources, it may be more convenient for producers to seek out their own solutions to management concerns. This information, however, can come from biased sources and may not meet the individual needs of the producer. Educators are specially trained to work collaboratively with members of their industry and often have years of experience in their support. Less than half of the surveyed participants had maintained records of quantifiable data relevant to their livestock's performance – there are many benefits of keeping sound records and the use of quantitative genetic analysis is simply one method of utilizing collected data.

Findings from this study revealed that the age of the small ruminant producers who participated had widely ranged. This may contribute to differences in learning styles and preferred methods of course delivery amongst clients. Educators should not only become more aware of the learning differences that may exist; they must also learn to adapt to

satisfy these educational needs. The use of more hybrid-type courses may also increase participation for individuals with other work or family obligations.

Finally, educators should remain current on their knowledge of new ideas and practices. More emphasis should be placed on continuing education requirements for Extension educators and other industry representatives. Educators should also feel a personal obligation to satisfying the educational needs of their community members, and this includes feeling confident about the recommendations being made. Academic journals such as *Small Ruminant Research* have been developed to provide these specific resources to leaders and members of the sheep and goat industries.

In summary, it is recommended:

1. Educators should be performing assessments of their communities to identify the needs of small ruminant producers.
2. Educators should be aware of the diverse learning styles that exist amongst a population.
3. Educators should continue to increase their knowledge and awareness of innovations that may be of benefit to their clients.

Recommendations for Future Research:

There is a special need for researchers to identify research topics relevant to small ruminant production in the United States. A majority of the present literature on sheep and goats comes from underdeveloped areas of the world where these animals are significant to their livelihood. It should be recognized, however, that much of this research does not apply to the economic factors of production that exist in the United

States. Small ruminants are often competing with larger industries that have had the advantage of being recognized and supported by researchers and economists alike.

Innovations that have been developed for other livestock species can sometimes be transferred to small ruminants successfully, however the industry would benefit greatly from recommendations made specifically for sheep and goats. Small ruminants are often disadvantaged in both the support and economic resources that are available to them. Sheep and goat are unique in that they have not yet been converted into the vertical integration management systems like poultry and swine and have not seen the wide-scale commercialization frequent to the dairy and beef cattle industries. Small ruminants remain heavily dependent on forage-based rations and are consequently subjected to management concerns unique to themselves.

The social behaviors of small ruminant producers may also be characteristics unique to this industry. While literature exists to explain some of the phenomena that influences livestock producers' decisions and behaviors, the industry would benefit from an increased emphasis on the social sciences. These findings may serve to be pivotal in the development of more complex models of economics or innovation diffusion. It may often be seen that researchers in the animal sciences and researchers in the social sciences are working independently, however the two disciplines must work harmoniously to achieve the greatest impacts within the industry.

It was found that the variables identified in the study were not significant predictors the adoption of quantitative genetic analysis strategies in small ruminants. Researchers should evaluate the variables influencing the adoption of quantitative genetic analysis more comprehensively so that a multifactorial model could eventually be developed with

greater accuracy. The conceptual framework of this study may be tailored to the support future research efforts on this topic.

In summary, recommendations for future research are:

1. Researchers should focus efforts on identifying topics relevant to small ruminant production in the United States.
2. Researchers should continue to represent the unique characteristics of the small ruminant industry compared to other livestock sectors.
3. Researchers should continue to study the social characteristics of small ruminant producers to make improved inferences about their decision-making behaviors.
4. Researchers should study the use of independent predictor variables in predicting the adoption of quantitative genetic analysis in small ruminants.

References

Abraham, H.C., Murphey, C.E., Cross, H.R., Smith, G.C., Franks, W.J. (1980). Factors affecting beef carcass cutability: An evaluation of the USDA yield grades for beef. *Journal of Animal Science*, 50(5), 841-851.

American Boer Goat Association. (n.d.). ABGA History. Retrieved from American Boer Goat Association: http://abga.org/about-abga/history/

American Wool Council. (n.d.) Wool Grades and the Sheep that Grow the Wool. Retrieved from the American Sheep Industry Association: http://d1cqrq366w3ike.cloudfront.net/http/DOCUMENT/SheepUSA/Wool_Grades_and_the_Sheep_that_Grow_the_Wool_Scan.pdf

Andrews, N. (2017). Psychosocial factors influencing the experience of sustainability professionals. *Sustainability Accounting, Management and Policy Journal*, (8)4, 445-469.

Azjen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, (50), 179-211.

Baumgart-Getz, A., Prokopy, L.S., Floress, K. (2012). Why farmers adopt best management practice in the United States: A meta-analysis of the adoption literature. *Journal of Environmental Management*, (96), 17-25.

Baruch, Y., Holtom, B. C. (2008). Survey response rate levels and trends in organizational research. *Human Relations*, 61(8), 1139-1160.

Bergevoet, R.H.M., Ondersteijn, C.J.M., Saatkamp, H.W., Van Woerkum, C.M.J., Huirne, R.B.M. (1995). Entrepreneurial behavior of Dutch dairy farmers under a milk quota system: Goals, objectives and attitiudes. *Agricultural Systems*, (80), 11-21.

Bland, J. M., Altman, D. G. (1997). Statistics notes: Cronbach's alpha. *Bmj*, 314.

Borges, J. A. R., Lansink, A. G. J. M. O., Ribeiro, C.M., Lutke, V. (2014). Understanding farmers' intention to adopt improved natural grassland using the theory of planned behavior. *Livestock Science*, (169), 163-174.

Boyazoglu, J., Hatziminaoglou, I., Morand-Fehr, P. (2005). The role of the goat in society: Past, present and future perspectives for the future. *Small Ruminant Research*, (60), 13-23.

Cappai, M.G., Picciau, M., Nieddu, G., Bitti, M.P.L., Pinna, W. (2014). Long term performance of RFID technology in the large-scale identification of small ruminants through electronic ceramic boluses: Implications for animal welfare and regulation compliance. *Small Ruminant Research*, 117(2), 169-175.

Cary, J.W., Holmes, W.E. (1982). Relationships among farmers' goals and farm adjustment strategies: Some empirics of a multidimensional approach. *Australian Journal of Agricultural Economics*, (26)2, 114-130.

Casey, N., Webb, E. (2010). Managing goat production for meat quality. *Journal of Small Ruminant Research*, 218-224.

Castel, J.M., Ruiz, F.A., Mena, Y., Sanchez-Rodriguez, M. (2010). Present situation and future perspectives for goat production systems in Spain. *Small Ruminant Research*, (89), 207-210.

Cawley, A., O'Donoghue, C., Heanue, K., Hilliard, R., Sheehan, M. (2018). The impact of Extension service on farm-level income: An instrumental variable approach to combat endogeneity concerns. *Applied Economic Perspectives and Policy*, (40)4, 585-612.

Chao-Ying, J.P., Kuk, L.L., Ingersoll, G. M. (2002). An introduction to logistic regression analysis and reporting. *The Journal of Educational Research*, (96), 3-14.

Christensen, O. F., & M. S. Lund. (2010). Genomic prediction when some animals are not genotyped. *Genetics Selection Evolution*, (42), 2.

Christman, C., Sponenberg, D. P., & Bixby, D. E. (1997). A Rare Breeds Album of American Livestock.

Connor, C.G. (1921). A brief history of the sheep industry in the United States. *Agricultural History Society Papers*, (1), 93-94.

Department of Agriculture, Forestry and Fisheries. (2012). A profile of the South African goat market value chain. Pretoria, South Africa: Department of Agriculture, Forestry, and Fisheries.

Dietmann, P., Tranel, L. (2009). The Wisconsin Goat Dairy Profitability Project. Wisconsin Department of Agriculture, Trade, and Consumer Protection. Madison, Wisconsin

Dillman, D. A. (2000). Mail and internet surveys: The tailored design method (2nd ed.). New York: Wiley.

Dillman, D. A., Smyth, J. D., Christian, L. M. (2014). Internet, Phone, Mail, and Mixed-Mode Surveys: The Tailored Design Method, (4th Ed.) Hoboken, New Jersey. John Wiley & Sons, Inc.

Dodunski, G. (2014). Knowledge transfer to farmers. *Small Ruminant Research*, (118), 103-105.

Dubeuf, J. P. (2014). Science, technology, innovation and governance for the goat sectors. *Small Ruminant Research*, (121), 2-6.

Egziabher, K. G., Mathijs, E., Maertens, M., Deckers, J., Bauer, H. (2011) Extension participation, household income and income diversification: a system equations approach. Paper presented at the Centre for the Study of African Economies. Oxford, UK.

Ensminger, M. E. (2002). Sheep and Goat Science, 6th Edition.

Epplin, F. M., Tice, T. F. (1986). Influence of crop and farm size on adoption of conservation tillage. *Journal of Soil and Water Conservation,* (41)6, 424-427.

Fernandez-Cornejo, J., Hendricks, C., Mishra, A. (2005). Technology adoption and off-farm household income: The case of herbicide-tolerant soybeans. *Journal of Agricultural and Applied Economics,* (37)3, 549-563.

Fernandez-Cornejo, J., Nehring, R., Hendricks, C., Southern, M., Gregory, A. (2007). *Off-farm Income, Technology Adoption and Farm Economic Performance.* Economic Research Report No. 7234. Washington D.C. US Department of Agriculture.

Fogli, J., & Herkenhoff, L. (2018). Conducting Survey Research: A Practical Guide. New York, NY. Business Expert Press.

Fthenakis, G.C., Papadopoulos, E. (2018). Impact of parasitism in goat production. *Small Ruminant Research,* (163), 21-23.

Garcia, C., Galdino, M., Dorward, P., Rehman, T. (2012). Farm and socio-economic characteristics of smallholder milk producers and their influence on technology adoption in Central Mexico. *Tropical Animal Health and Production,* (44)6, 1199-1211.

Gargiulo, J.I., Eastwood, C.R., Garcia, S.C., Lyons, N.A. (2018). Dairy farmers with larger herd sizes adopt more precision dairy technology. *Journal of Dairy Science,* (10)6, 5466-5473.

Gilbert, W., Rushton, J. (2018). Incentive perception in livestock disease control. *Journal of Agricultural Economics*. (69)1, 243 – 261.

Gillespie, J., Qushim, B., Nyaupane, N., McMillin, K. (2015). Breeding technologies in U.S. meat goat production: Who are the adopters and how does adoption impact productivity? *Agricultural and Resource Economic Review,* (44)3, 315-339.

Gizaw, S., Komen, H., Arendonk, J. A. (2010). Participatory definition of breeding objectives and selection indexes for sheep breeding in traditional systems. *Livestock Science,* 67-74.

Goolsby, M.K., Leite-Browning, M.L., Browning Jr, R. (2017). Evaluation of parasite resistance to commonly used commercial anthelminthics in meat goats on humid subtropical pasture. *Small Ruminant Research,* (146), 37-40.

Gowda, M.J.C., Dixit, S. (2015). Influence of farmers education level on comprehending, acting-upon and sharing of agro advisories. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, (116)2, 167 – 172.

Happe, K. (2004). Agricultural policies and farm structure: Agent-based modelling and application to EU policy reform. Studies on the Agricultural and Food Sector in Central and Eastern Europe, (Vol. 30). Institute of Agricultural Development in Central and Eastern Europe.

Hazel, L.N. (1943). The genetic basis for constructing selection indexes. *Genetics*, 28(6), 476-490.

Hendra, R., Hill, A. (2018) Rethinking response rates: New evidence of little relationship between survey response rates and nonresponse bias. *Evaluation Review*, 1-24.

Hektoen, L. (2012). An outbreak of caseous lymphadenitis in a Norwegian ram circle and attempts to eliminate the disease. *Small Ruminant Research*, (106), 25-26.

Howard, J. T., Rathje, T. A., Bruns, C. E., Wilson-Wells, D. F., Kachman, S. D., Spangler, M. L. (2018) The impact of selective genotyping on the response to selection using single-step genomic best linear unbiased prediction. *Journal of Animal Science,* 4532-4542.

Holst, P.J. (1999) Recording and on-farm evaluations and monitoring: Breeding and selection. *Small Ruminant Research,* 34(3), 197-202.

Iniguez, L. (2011). The challenges of research and development of small ruminant production in dry areas. *Small Ruminant Research*, 98(1), 12-20.

Jaenisch, R., Bird, A. (2003). Epigenetic regulation of gene expression: how the genome integrates intrinsic and environmental signals. *Journal of Nature Genetics*, 245-524.

Kairu-Wanyoike, S., Kaitibie, S., Taylor, N., Gitau, G., Heffernan, C., Schnier, C., McKeever, D. (2013). Exploring farmers preferences for contagious bovine pleuropneumonia vaccination: A case study of Narok District of Kenya. *Preventative Veterinary Medicine*, 356-369.

Khanal, A.R., Gillespie, J., MacDonald, J. (2010). Adoption of technology, management practices, and production systems in US milk production. *Journal of Dairy Science*, (93)12, 6012-6022.

Kumm, K. I. (2009). Profitable Swedish lamb production by economies of scale. *Small Ruminant Research,* (81), 63-69.

Lindner, J. R., Murphy, T. H., Briers, G. E. (2001). Handling nonresponse in social science research. *Journal of Agricultural Education*, (44)4, 43-53.

Liu, T., Bruins, R. J.F., Heberling, M T. (2018). Factors influencing farmers' adoption of best management practices: A review and synthesis. *Sustainability*, (10)2.

Lungu, N.S., Muchenje, V. (2018). Check all-that-apply (CATA) analysis of lamb management practices and constraints faced by resource-limited sheep farmers in two ecologically different regions of South Africa. *Small Ruminant Research*, (160), 107-115.

McInerney, J., Turner, M.M. (1991). *Patterns, performance and prospects in farm diversification.* Exetor, Devon. University of Exeter, Agricultural Economics Unit.

McKellar, Q.A. (2006). The health of the sheep industry and the medicines to maintain it. *Small Ruminant Research*. (62) 7-12.

Micheels, E. T., Nolan, J. F. (2016). Examining the effects of absorptive capacity and social capital on the adoption of agricultural innovations: A Canadian Prairie case study. *Agricultural Systems*, (145), 127-138.

Milani, F.X., Wendorff, W.L. (2011). Goat and sheep milk products in the United States. *Small Ruminant Research*, (101) 134-139.

Mohlatole, R. P., Dzomba, E. F. (2015). Addressing production challenges in goat production systems of South Africa: The genomics approach. *Small Ruminant Research*.

Montossi, F., Barbieri, I. D., Ciappesoni, G., Ganzabal, A., Banchero, G., Luzardo, S., Julian, R. S. (2013). Intensification, diversification, and specialization to improve the competitiveness of sheep production systems under pastoral conditions: Uruguay's case. *Animal Frontiers*, (3)3, 28-35.

Moore, D.L., Folwell, R.J., DeBoer, A.J., Bari, J., Mbweria, S. (1991). Small ruminants in western Kenya: Producer socioeconomic status in relation to herd health. *Small Ruminant Research*, (4), 323-338.

Morand-Fehr, P., Boutonnet, J.P., Devendra, C., Dubeuf, J.P., Haenlein, G.F.W., Holst, P., Mowlem, L., Capote, J. (2004) Strategies for goat farming in the 21st century. *Small Ruminant Research*, (51), 175-183.

Morand-Fehr, P., Lebbie, S.H.B. (2004). Proposals for improving the research efficiency in goats. *Small Ruminant Research*, (51), 145-153.

Morris, S.T. (2009). Economics of sheep production. *Small Ruminant Research*, (86), 59-62.

Mulder, H., Bijma, P., & Hill, W. (2007). Prediction of breeding values and selection response with genetic heterogeneity of environmental variance. *Genetics*, 1895-1910.

Naspetti, S., Mandolesi, S., Buysee, J., Latvala, N., Philippa, P., Susanne, V. L., Ellen, J., Zanoli, R. (2017). Determinants of the acceptance of sustainable production strategies among dairy farmers: Development and testing of a modified technology acceptance model. *Sustainability*, (9)10.

National Agricultural Statistics Service, Agricultural Statistics Board, United States Department of Agriculture. (2011). Overview of the united states sheep and goat industry. United States Department of Agriculture.

National Agricultural Statistics Service, Agricultural Statistics Board, United States Department of Agriculture. (2017). Overview of the united states sheep and goat industry. United States Department of Agriculture.

Ngere, L., Burke, J.M., Herring, A.D., Sanders, J.O., Craig, T.M., Van Wyk, J.A., Riley, D.G. (2017). Utilization of year-round data in the estimation of genetic parameters for internal parasite resistance traits in Dorper sheep. *Small Ruminant Research*, (151), 5-10.

Nielsen, H.M., Olesen, I., Navrud, S., Kolstad, K., Amer, P. (2010) How to consider the value of farm animals in breeding goals. A review of current status and future challenges. *Journal of Agricultural and Environmental Ethics*, (24), 309-330.

Norris, D., Ngambi, J., Benyi, K., Mbajiorgu, C. (2011). Milk production of three exotic dairy goat genotypes in Limpopo province, South Africa. *Asian Journal of Animal Veterinary Advancements*, 274-281.

Notter, D. (2011). NSIP EBV Notebook. Retrieved from National Sheep Improvement Plan: http://nsip.org/wp-content/uploads/2015/03/NSIP-EBV-Descriptions-FINAL-1.16.15.pdf

Notter, D. (2016). Should you join NSIP? Virginia Shepherds' Symposium.

Olaizola, A.M., Chertouh, T., Manrique, E. (2008). Adoption of a new feeding technology in Mediterranean sheep farming systems: Implications and economic evaluation.

Olivier, J., Cloete, S., Schoeman, S., Muller, C. (2005). Performance testing and recording in meat and dairy goats. *Journal of Small Ruminant Research*, 83-93.

Owens, T., Hoddinott, J., Kinsey, B. (2003). The impact of agricultural extension on farm production in resettlement areas of Zimbabwe. *Economic Development and Cultural Change*, (51)2, 337-357.

Peacock, C. (2005). Goats – A pathway out of poverty. *Small Ruminant Research*, (60), 179-186.

Peel, D., Berry, H. L., Schirmer, J. (2016). Farm exit intention and wellbeing: A study of Australian farmers. *Journal of Rural Studies*, (47), 41-51.

Perry-Hill, R., & Prokopy, L. (2014). Improving environmental management on small-scale farms: Perspectives of Extension educators and horse farm operators. *Environmental Management,* (55), 31-42.

Poku, S. O. (2009). Analysis of the current status of small-scale sheep and goat production by farmers of different age groups in the Jirapa and Lambussie Districts, Ghana. *Journal of Developments in Sustainable Agriculture,* (4), 149 – 159.

Ritter, C., Adams, C. L., Kelton, D. F., Barkema, H. W. (2019). Factors associated with dairy farmers' satisfaction and preparedness to adopt recommendations after veterinary herd health visits. *Journal of Dairy Science,* (102)5 4280-4293.

Rogers, E. M. (2008). Diffusion of innovations (5th ed.). New York, NY. The Free Press, A Division of Simon & Schuster, Inc.

Ryan, R. (2009). Self-determination theory and wellbeing. Wellbeing in Developing Countries (WeD). Retrieved from: http://www.bath.ac.uk/soc-pol/welldev/wed-new/network/research-review/Review_1_Ryan.pdf

Safari, E., Fogarty, N., Gilmour, A. (2005). A review of genetic parameter estimates for wool, growth, meat and reproduction traits in sheep. *Livestock Production Science,* 271-289.

Safari, E., Fogarty, N., Gilmour, A., Atkins, K., Mortimer, S., Swan, A., Van Der Werf, J. (2007). Genetic correlations among and between wool, growth and reproduction traits in Merino sheep. *Journal of Animal Breeding and Genetics*, 65-72.

Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *The Turkish Online Journal of Educational Technology*, (5), 14-23.

SanCristobal-Gaudy, M., Bodin, L., Elsen, J., Chevalet, C. (2001). Genetic components of litter size variability in sheep. *Genetic Selection of Evolution,* 249-271.

Sargison, N.D. (2013). Understanding the epidemiology of gastrointestinal parasitic infections in sheep: What does a fecal helminth egg count tell us? *Small Ruminant Research,* (110), 78-81.

Saris, W. E., Revilla, M. (2016). Correction for measurement error in survey research: Necessary and possible. *Social Indicators Research,* 1005-1020.

Saxby, H., Gkartzios, M., Scott, K. (2017). 'Farming on the edge': Wellbeing and participation in agri-environmental schemes. *Sociologio Ruralis*. (58)2.

Seals, R. G. (1991). The formation of agricultural and rural development policy with emphasis on African-Americans: II. The Hatch-George and Smith-Lever Acts. *Agricultural History*. (65)2, 12-34.

Sebatjane, P. N., Njuho, P. M., Tsotetsi-Khambule, A. M. (2018). Statistical models for helminth fecal egg counts in sheep and goats. *Small Ruminant Research*, (170) 26-30.

Snowder, G., Van Vleck, L. (2003). Estimates of genetic parameters and selection strategies to improve the economic efficiency of post weaning growth in lambs. *Journal of Animal Science.*

Sun, D., Hyland, P., Bosch, O. (2014). A systemic view of innovation adoption in the Australian beef industry. *Systems Research and Behavioral Science*, (32)6.

Tey, Y.S., Brindal, M. (2012). Factors influencing the adoption of precision agricultural technologies: A review for policy implications. *Precision Agriculture,* (13)6, 713-730.

Triantaphyllopoulos, K. A., Ikonomopoulos, I., Bannister, A. J. (2016). Epigenetics and inheritance of phenotype variation in livestock. *Journal of Epigenetics and Chromatin*.

United States Department of Agriculture. (n.d.). National Agricultural Statistics Service. Sheep and Goat Quick Stats.

Valeeva, N.I., Van Asseldonk, M.A.P.M., Backus, G.B.C. (2011). Perceived risk and strategy efficacy as motivators of risk management strategy adoption to prevent animal disease in pig farming. *Preventative Veterinary Medicine,* (102)4, 284-295.

Wang, S. L. (2014). Cooperative Extension System: Trends and economic impacts on U.S. agriculture. *Choices*, (29) 1-8.

Whitley, N.C., Oh, S.H., Lee, S.J., Schoenian, S., Kaplan, R.M., Storey, B., Terrill, T.H., Mobini, S., Burke, J.M., Miller, J.E., Perdue, M.A. (2014). Impact of integrated gastrointestinal nematode management training for U.S. goat and sheep producers. *Veterinary Parasitology*, (200), 271-275.

Williams, G.W., Anderson, D.P. (2016). Small ruminant symposium: Enhancing small ruminant profitability. *Journal of Animal Science,* (94)5, 1726.

Yang, W., Chen, C., Steibel, J.P., Ernst, C.W., Bates, R.O., Zhou, L., Tempelman, R.J. (2015). A comparison of alternative random regression and reaction norm models for whole genome predictions. *Journal of Animal Science*, (93)6, 2678-2692.

Zishiri, O., Cloete, S., Olivier, J., Dzama, K. (2013). Genetic parameters for growth, reproduction and fitness traits in the South African Dorper sheep breed. *Journal of Small Ruminant Research,* 39-48.

Appendix A: Survey Instrument

Sheep and Goat Production System Survey

Please answer the following questions about your sheep and/or goat operation. You may choose to skip any question you do not wish to answer.

Eligibility

1. Are you the owner or primary manager of a sheep and/or goat operation?
    a. Yes – Goat
    b. Yes – Sheep
    c. Yes- Both
    d. No
2. Is your farm located in the State of New York?
    a. Yes
    b. No

*If you answered "No" to either of the questions above, you do not meet the specifications of this research study. Please stop here and contact the researcher. Thank you.

3. What is the primary purpose of the animals that you raise?

Sheep	Goats
a. Meat	a. Meat
b. Milk	b. Milk
c. Fiber	c. Fiber
d. Other*	d. Other*
*Other _____	_____

4. What are the secondary purposes, if any?

Sheep	Goats
a. Meat	a. Meat
b. Milk	b. Milk
c. Fiber	c. Fiber
d. Other*	d. Other*
*Other _____	_____

5. What was the number of females bred in 2017 in your herd?
    Sheep _____ Goats _____
6. What was the number of breeding males used in 2017 in your herd?
    Sheep _____ Goats _____
7. Did you utilize artificial insemination during the 2017 breeding season?
    a. Yes, Goats b. Yes, Sheep c. No
8. What was the number of offspring born in 2018 in your herd?
    Sheep _____ Goats _____

9. Is your herd operating at an accelerated kidding rate? i.e. does or ewes are bred to kid/lamb more than once in a twelve-month period.
    a. Yes, Goats b. Yes, Sheep c. No
10. Is your enterprise part of a larger diversified farm business?
    a. Yes
    b. No
11. What percentage of your farm profit is generated through sheep/goat enterprise?
    Sheep _____ Goats _____

12. Categorize the income from your sheep/goat business:
    a. Sole income for household
    b. Main income for household
    c. Supplemental income for household
    d. Not a source of income for household
13. What was the income received from your sheep/goat business in 2017?
    (1) $0-20,000 (2) $20,001-40,000 (3) $40,001-60,000 (4) $60,001 – 80,000 (5) $80,001- 100,000 (6) $100,001 + (7) Prefer not to answer
    Please indicate income range on line below where it applies. Example: If you received $15,000 in sales from sheep wool in 2017, place a "1" on the line for Fiber in the Sheep column.

Sheep	Goats
a. Meat ___	a. Meat ___
b. Milk ___	b. Milk ___
c. Fiber ___	c. Fiber ___
d. Other* ___	d. Other* ___
*Other _____	_____

14. How many paid employees, besides yourself, are involved in your sheep/goat operation?
    a. Seasonal ____
    b. Part-time ____
    c. Full-time_____
    d. None ____
15. Does your farm sell live animals?
    a. Yes, Goats b. Yes, Sheep c. No
16. Select the following live animal markets you utilize:
    a. Auction through a sale barn
    b. Consigned sales
    c. Online Sales
    d. On-farm sales to consumers
    e. On-farm sales for breeding stock
    f. On-farm sales for show-type market animals

17. Does your farm use or market dairy products from your sheep/goats?
    a. Yes, Goats b. Yes, Sheep c. No
18. What type of dairy products are your marketing? If dairy products are for home-use only, please select home-use.
    a. Wholesale fluid milk
    b. Retail bottled milk
    c. Cheese
    d. Yogurt
    e. Soap
    f. Home-use
    g. Other
19. Does your farm use or market meat products from your sheep/goats?
    a. Yes, Goats b. Yes, Sheep c. No
20. What type of meat products are you offering? If meat products are for home-use only, please select home-use.
    a. Wholesale carcass
    b. Meat shares
    c. On-farm retail
    d. Farmer's market
    e. Home-use
    f. Other
21. Does your farm use or market fiber products from your sheep/goats?
    a. Yes, Goats b. Yes, Sheep c. No
22. What type of goat fiber are you producing? (Goat producers only)
    a. Mohair
    b. Cashmere
    c. Other _____
23. What type of fiber products are you offering? If fiber products are for home-use only, please select home-use.
    a. Wholesale raw fiber
    b. Wholesale processed fiber
    c. Retail processed fiber
    d. Retail fiber products
    e. Retail – value added products
    f. Home-use
    g. Other
24. Please list any other source of sheep/goat income generated through your business.

    _____

Goals for Operation

25. Please rank your thoughts on the importance of these statements towards the goals for your operation:

	Strongly Disagree (1)	Somewhat Disagree (2)	Neither Agree nor Disagree (3)	Somewhat Agree (4)	Strongly Agree (5)
Improving the profitability of my farm	○	○	○	○	○
Decreasing my farm's expenses	○	○	○	○	○
Improving animal performance	○	○	○	○	○
Producing animals resistant to disease and parasites	○	○	○	○	○
Producing animals that are more desirable at market	○	○	○	○	○

List any other goals that were not listed above:

_____

Record Keeping

26. Which records do you currently maintain for your sheep/goats? Select all that apply.

Sheep	Goat
○ Birth weight	○ Birth weight
○ Weaning weight	○ Weaning weight
○ Post weaning weight (90-120 days)	○ Post weaning weight (90-120 days)
○ Yearling weights	○ Yearling weights
○ Breeding dates	○ Breeding dates
○ Vaccination dates	○ Vaccination dates
○ Hoof trimming dates	○ Hoof trimming dates
○ FAMACHA scores	○ FAMACHA scores
○ Fecal Egg Count Scores	○ Fecal Egg Count Scores
○ Milk Weights	○ Milk Weights
○ Business Expenses	○ Business Expenses
○ Ribeye Area	○ Ribeye Area
○ Backfat thickness	○ Backfat thickness
○ None	○ None

27. Are there any other records you are currently maintaining that were not listed in the previous question?

_____

28. How do you currently use records in your herd and where would you like to use them in the future?

	Currently use records to...	Would like to use records to...
Identify high-performing animals in my herd/flock	○	○
Identify animals that require lower inputs	○	○
Create index values for individual animals	○	○
Market animals that out-perform herd/flock mates	○	○
Select replacement stock	○	○

Breeding System

29. What is most important to you when evaluating breeding stock?
    a. Visual conformation
    b. Pedigree
    c. Performance data
    d. Hardiness

30. How do you currently source male breeding stock?
    a. Purchase new sires
    b. Lease new sires
    c. Artificial insemination
    d. Select sires from own herd

31. How do you currently source female breeding stock?
    a. Purchase new stock
    b. Embryos
    c. Select from own herd
    d. Retain from AI breeding

32. Rank the following that are important to you when selecting genetics
    (1) Most important – (5) Least important
    ___ Health records
    ___ Performance program records
    ___ Pedigree
    ___ Conformation/Phenotype
    ___ Other

33. Have you ever considered calculating indexes or estimated breeding values within your own herd or flock?
    a. Yes
    b. No
    c. Not sure
    d. Currently do

34. How would you rank your current knowledge of indexes or estimated breeding values?
    a. I know a lot about it
    b. I know some things about it
    c. I have heard of it before
    d. I have not heard of it before

35. What are some barriers you feel are preventing you from making record-based breeding decisions?

	Strongly Disagree (1)	Somewhat Disagree (2)	Neither Agree nor Disagree (3)	Somewhat Agree (4)	Strongly Agree (5)
Time able to spend on sheep/goat enterprise	○	○	○	○	○
Labor cost associated with record keeping	○	○	○	○	○
Ability to obtain information for records	○	○	○	○	○
Management style does not allow for regular handling	○	○	○	○	○
Knowledge of how to use records	○	○	○	○	○

36. Rate the following statements about your general satisfaction with your sheep/goat enterprise

	Strongly Disagree (1)	Somewhat Disagree (2)	Neither Agree nor Disagree (3)	Somewhat Agree (4)	Strongly Agree (5)
I am satisfied with the profit I receive from my sheep/goat enterprise	○	○	○	○	○
I am satisfied with my ability to make decisions regarding my sheep/goat enterprise	○	○	○	○	○
I am satisfied raising sheep and/or goats	○	○	○	○	○
I am satisfied with the overall health of my herd	○	○	○	○	○
I am satisfied with the support and information resources available to me	○	○	○	○	○
I plan to continue raising sheep/goats in the next five years	○	○	○	○	○
I plan to expand my herd or flock in the next five years	○	○	○	○	○
I plan to expand the sheep/goat products that I offer in the next five years	○	○	○	○	○

Demographics

37. Have you ever attended any classes, webinars, or workshops for on-farm genetic evaluation strategies?
    a. Yes b. No

38. What organization offered that education experience? _____

39. Would you be interested in attending an educational course in the future?
    a. Yes b. No

40. What type of educational course would you prefer?
    a. Webinar
    b. Workshop
    c. Online course
    d. Other

41. How many years have you been raising sheep/goats? _____

42. Please indicate your gender _____

43. Please indicate your highest level of education
    a. High school
    b. Some college
    c. Associates degree
    d. Bachelor's degree
    e. Master's degree
    f. Doctoral degree

44. Please indicate your age. _____

Thank you for taking the time to complete this survey. Your input is greatly appreciated and contributes to the success of all sheep and goat education programs. Please follow instructions listed in cover letter for sending your responses back to the researcher.

Appendix B: Cover Letter

January 14, 2019

Michael Fiorentino
009 Ferguson Building
University Park, PA 16802

Dear Sheep and Goat Producer,

You are invited to volunteer to participate in a research study. This summary explains information about this research.

- The purpose of this research is to examine the perceptions of small ruminant producers on the utilization of improved herd or flock management strategies. This research seeks to describe the characteristics of producers who are engaging in these practices as well as identify potential barriers that may prevent the adoption of these tools.
- Participants are asked to complete a survey questionnaire that will capture information related to their current management practices, thoughts and beliefs pertaining to the adoption of innovative strategies, as well as some basic demographic information.
- *All information obtained from the survey will remain confidential*. The response data from participants will be assigned a code and stored separately from any information that may identify the participant. All information, both participant identification and responses, will be stored on a password protected computer. Any research publications resulting from the findings of the study will not include any identifying information of the participants.

If you have any questions or concerns, you should contact Michael Fiorentino at (xxx) xxx-xxxx or xxxxx@psu.edu. If you have any questions regarding your rights as a research subject or concerns regarding your privacy, you may contact the Penn State Office for Research Protections at 814-865-1775.

Your participation is voluntary, and you may decide to stop at any time. You do not have to answer any questions that you do not wish to answer. Your participation implies your voluntary consent to participate in the research.

Included in this folder is a copy of the survey questionnaire. Your responses will provide a valuable contribution to our sheep and goat industry and would be greatly appreciated. It is requested that responses be returned within one week of receiving this letter. Please do not hesitate to contact the research if additional accommodations are needed.

Thank you for your time,
Michael Fiorentino

Appendix C – Additional Tables and Figures

Figure C-1. Respondents who sell live goats

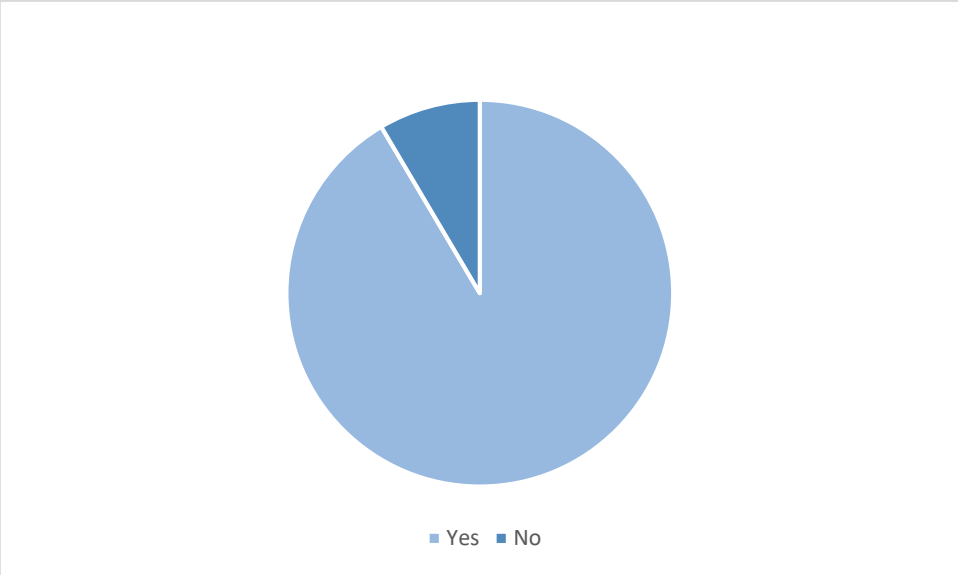


Figure C-2. Live goat markets utilized

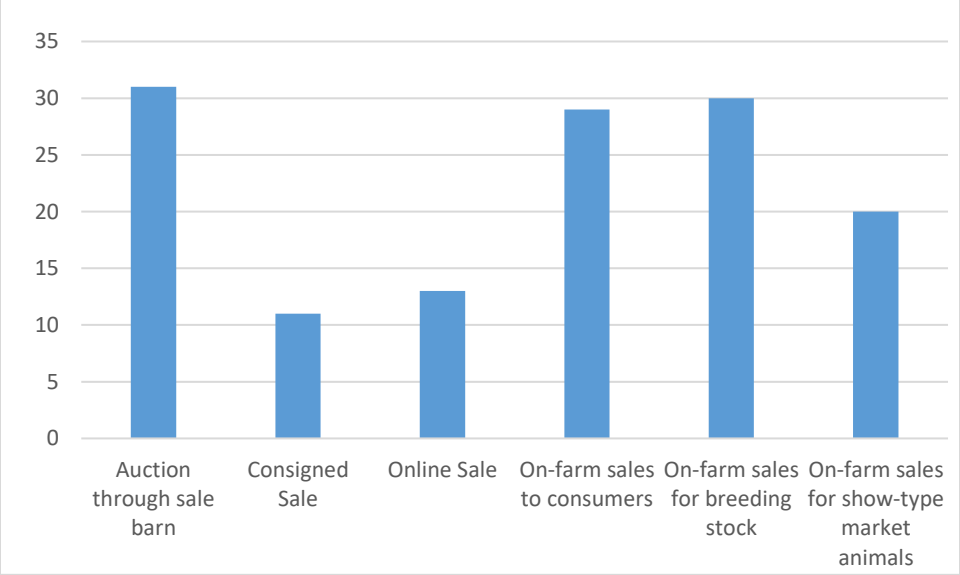


Figure C-3. Respondents who offer dairy goat products

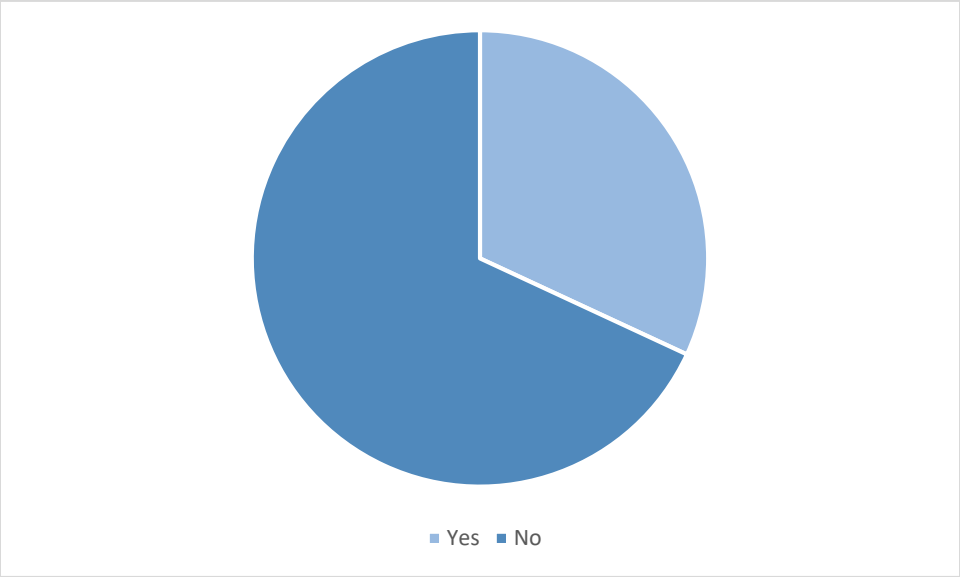


Figure C-4. Dairy goat products

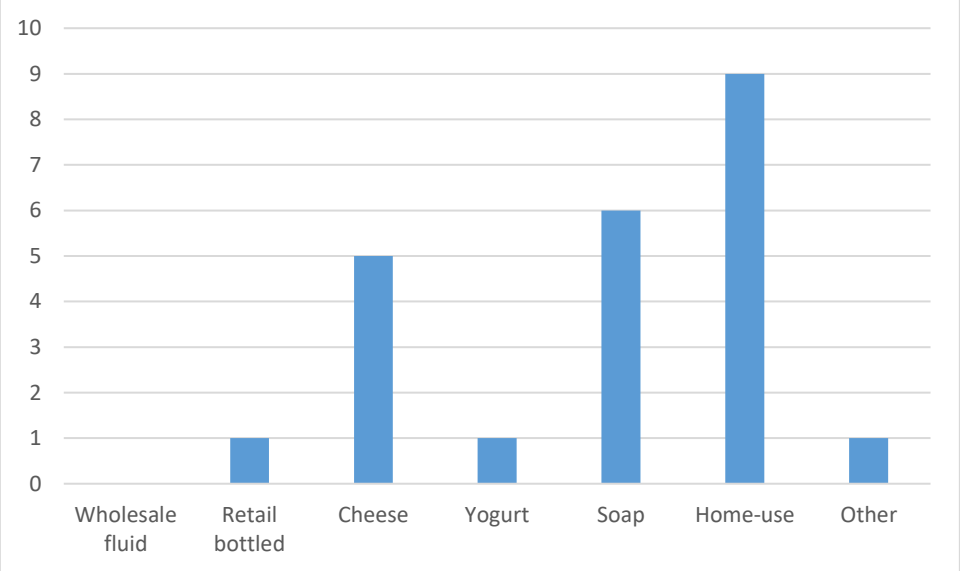


Figure C-5. Respondents who offer meat goat products

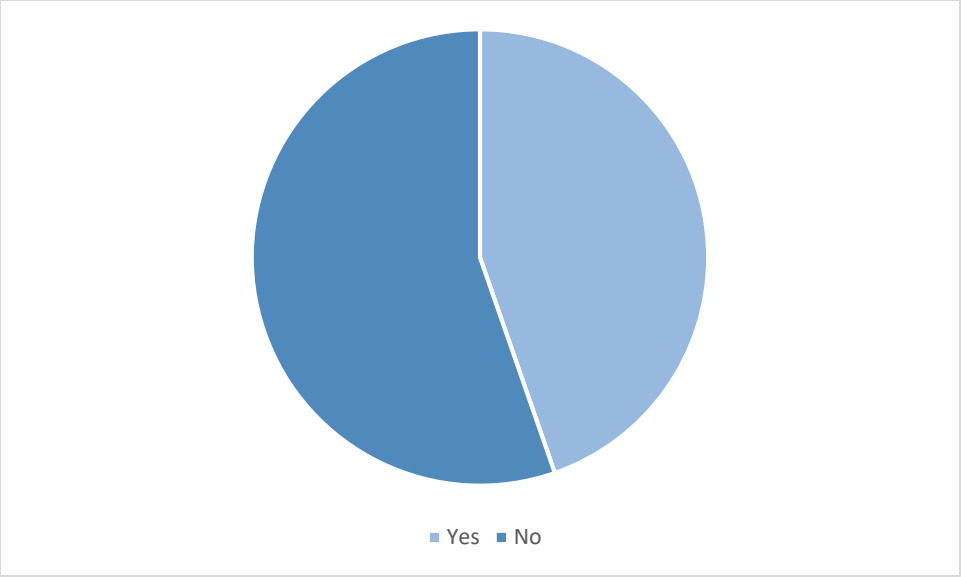


Figure C-6. Meat goat products

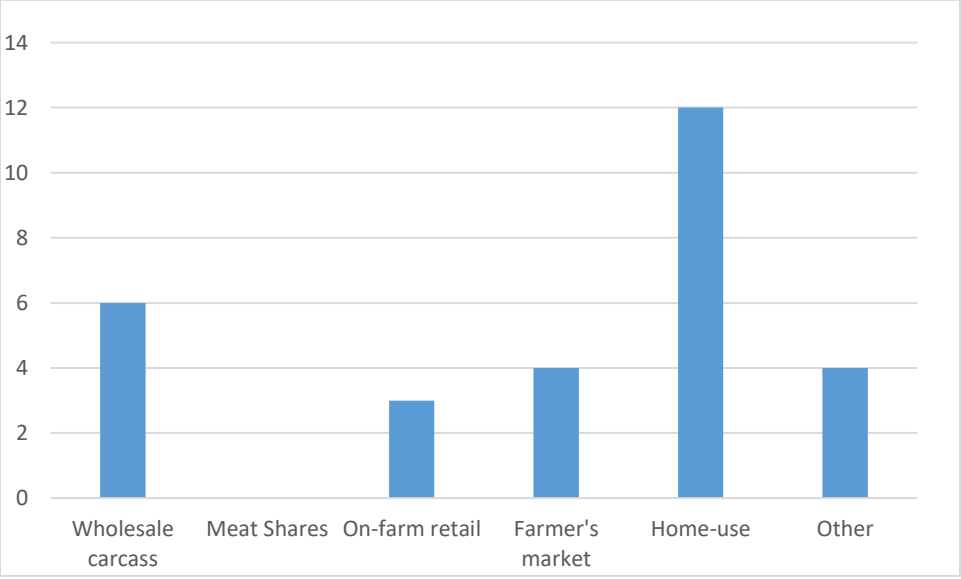


Figure C-7. Respondents who offer goat fiber products

Figure C-8. Types of goat fiber used

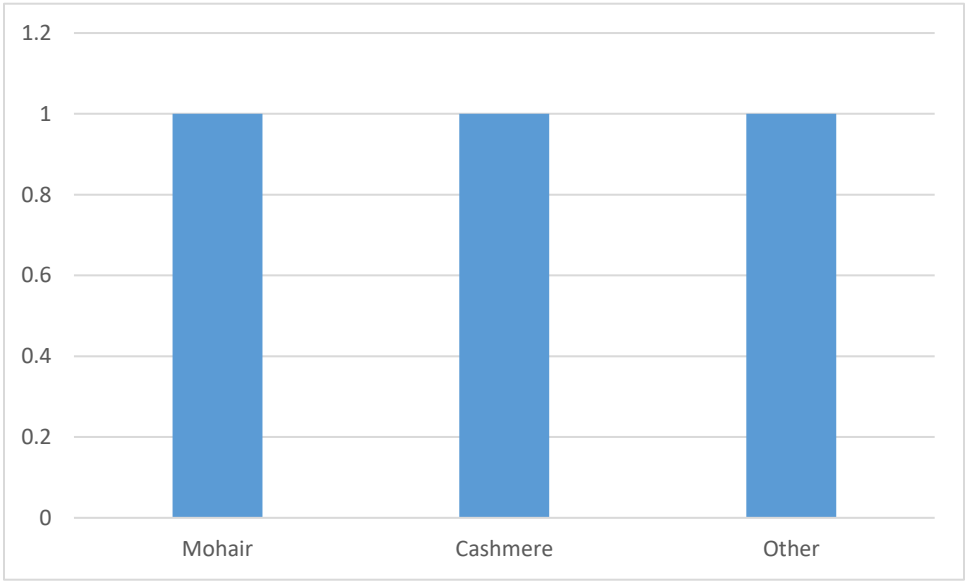


Figure C-9: Fiber goat products

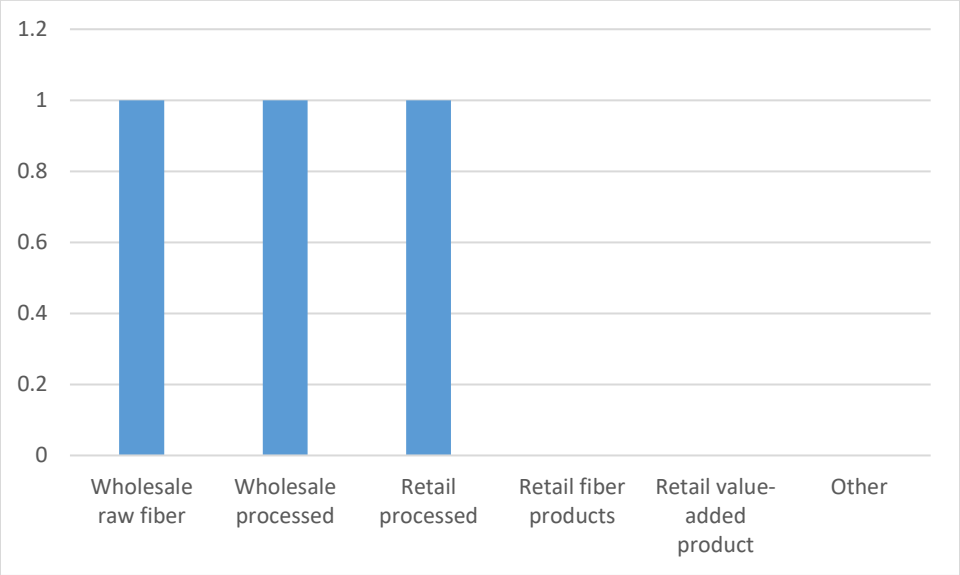


Figure C-10: Respondents who sell live sheep

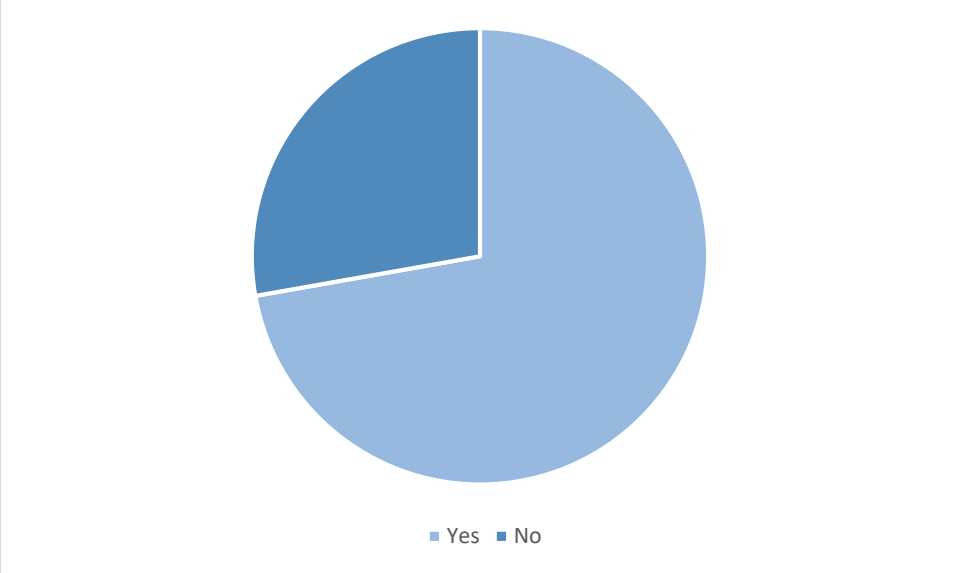


Figure C-11: Live sheep markets utilized

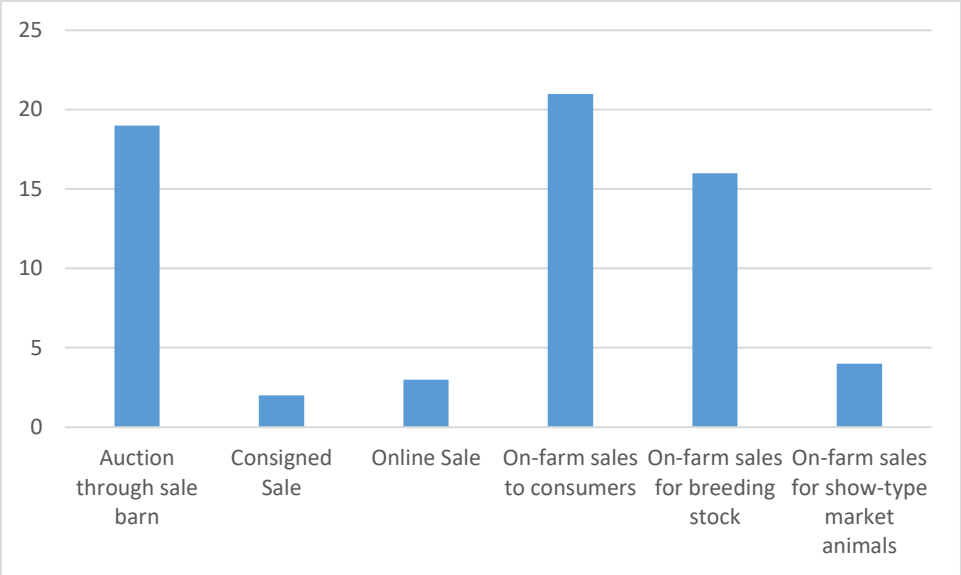


Figure C-12: Respondents who offer dairy sheep products

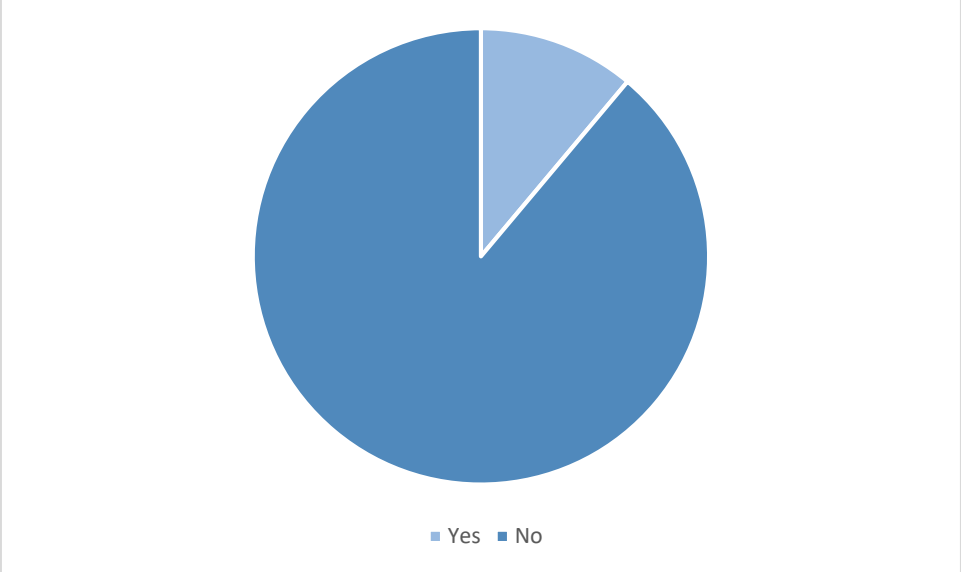


Figure C-13: Dairy sheep products

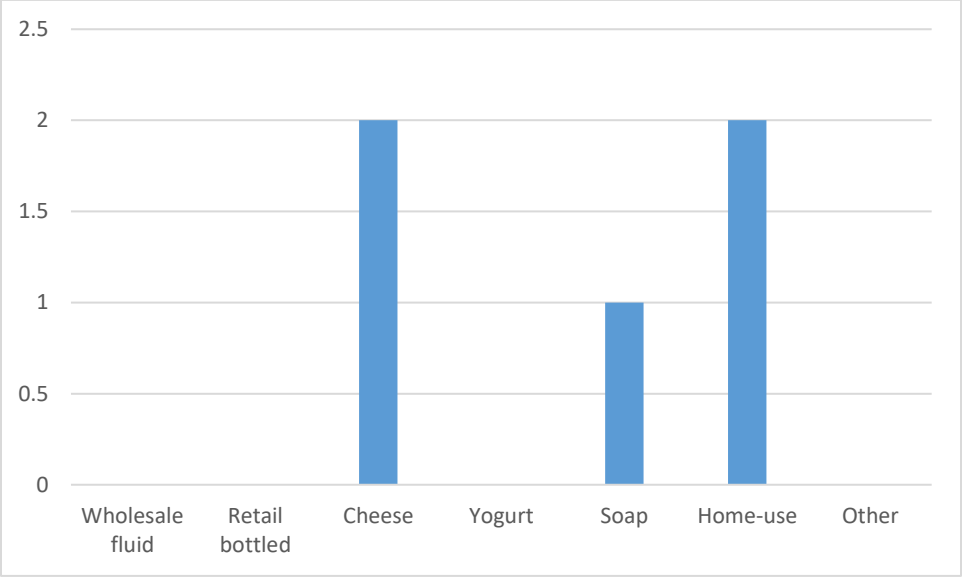


Figure C-14: Respondents who offer sheep meat products

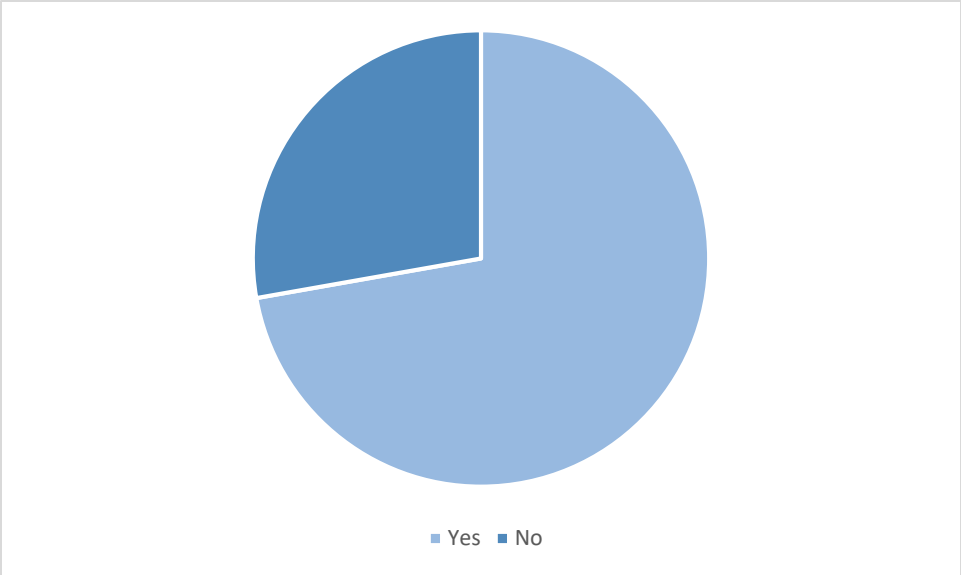


Figure C-15: Sheep meat products

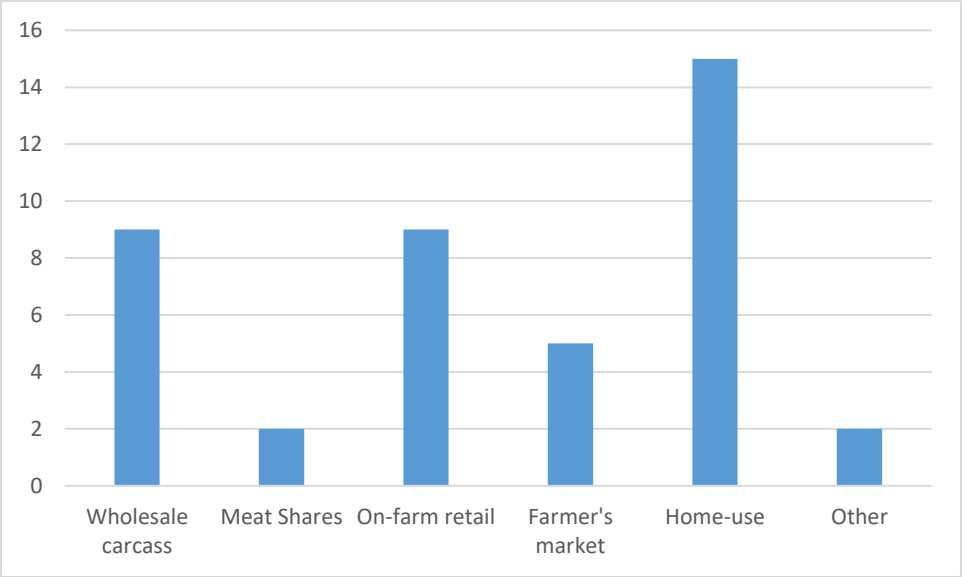


Figure C-16: Respondents who offer sheep fiber products

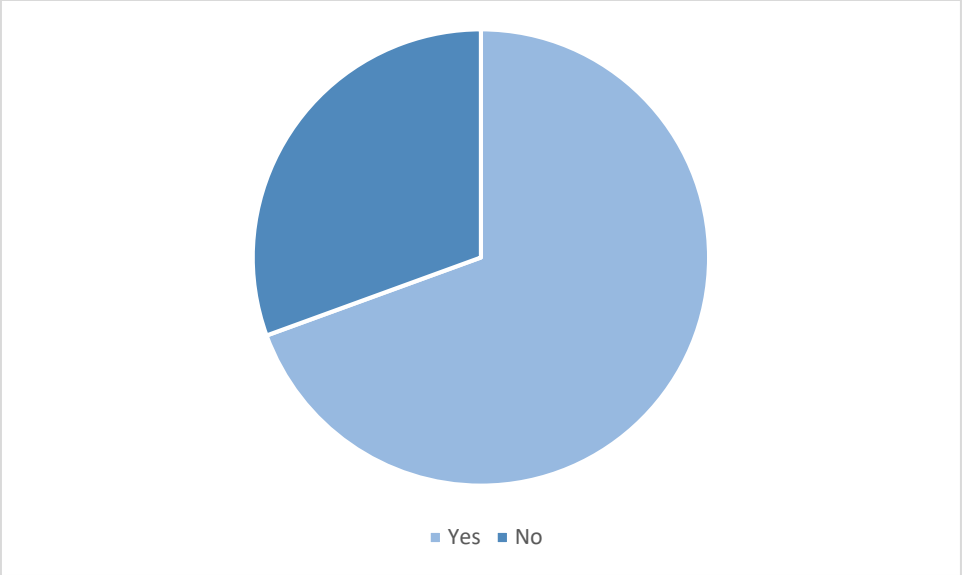


Figure C-17: Sheep fiber products

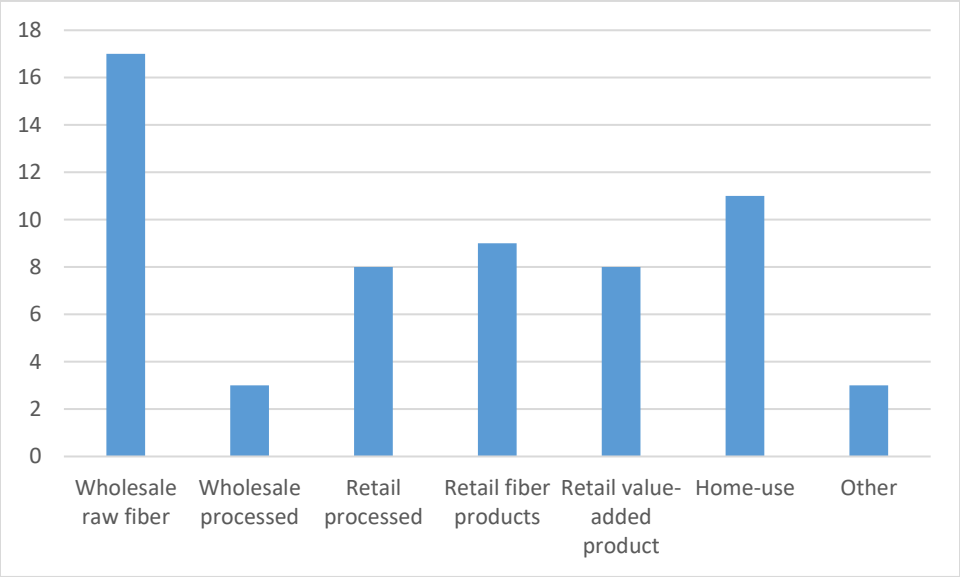


Figure C-18: Records kept on sheep and goats

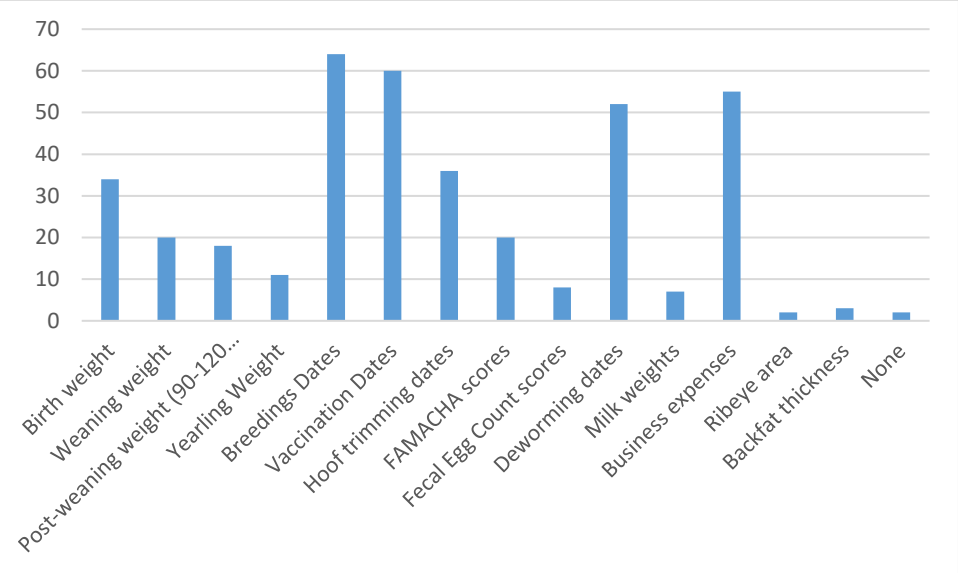


Figure C-19: Current record use in sheep and goats

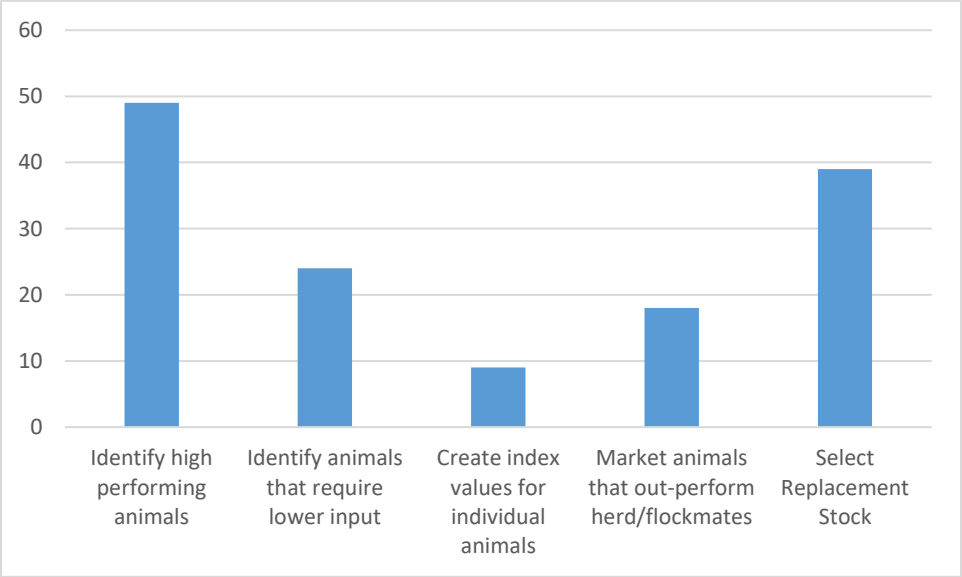


Figure C-20: Anticipated record use in sheep and goats

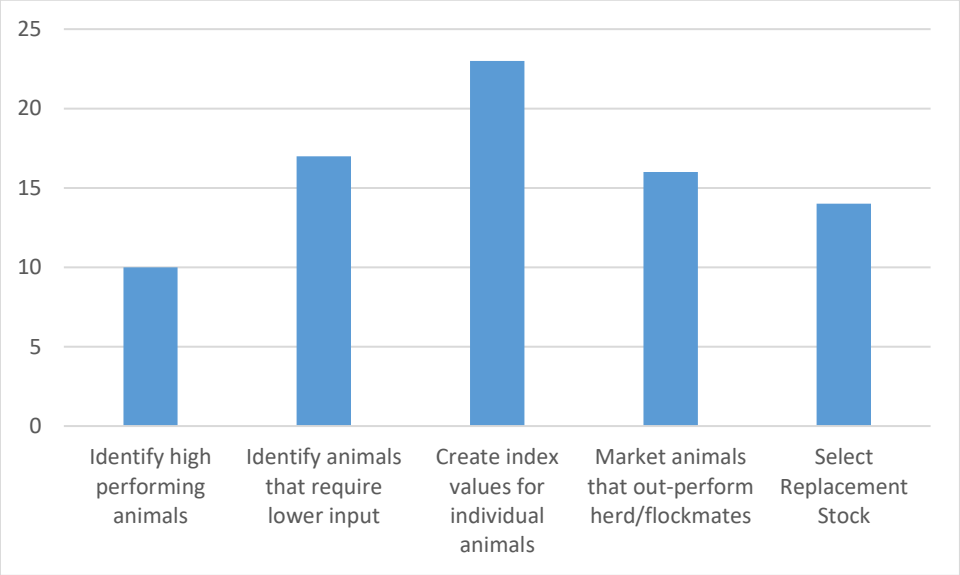


Figure C-21: Respondents who have attended a class, workshop, or webinar for on-farm genetic evaluation strategies

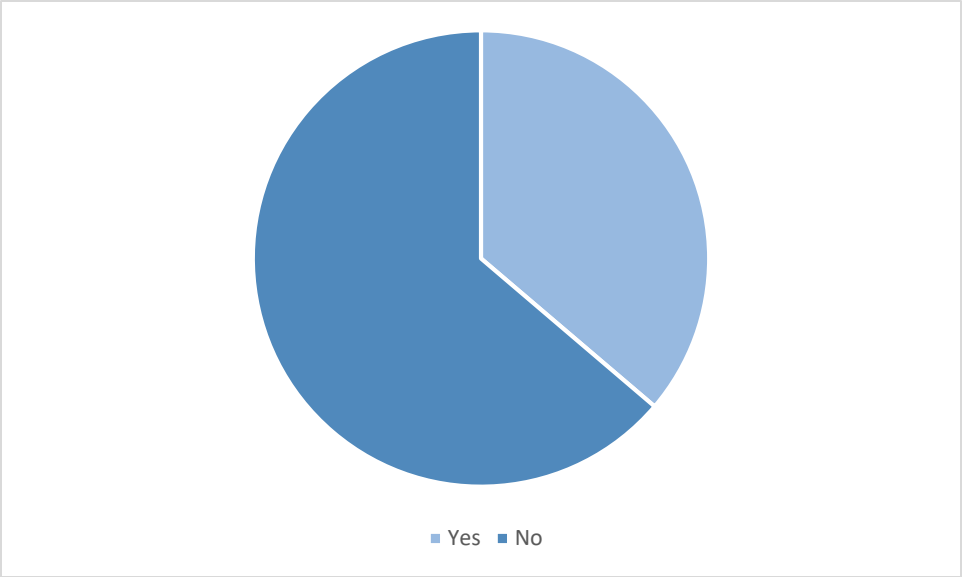


Figure C-22: Respondents interested in attending a future educational course

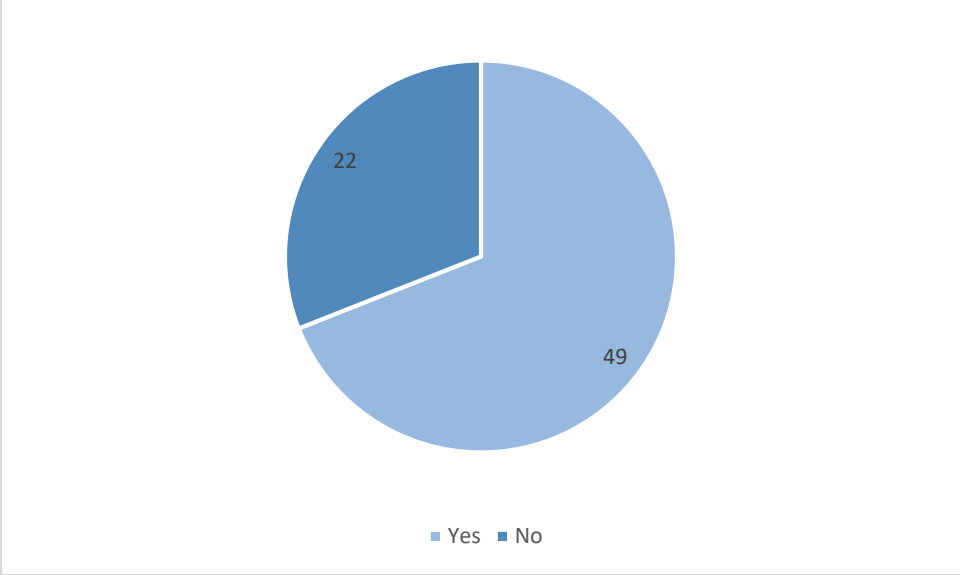


Figure C-23: Preferred course delivery method