Communicating agricultural model concepts and results to smallholder farmers in rural areas of southern Zimbabwe: sharing knowledge for a mutual benefit.

MSc Thesis - Plant Production Systems

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Abstract

The aim of this research is to communicate agricultural model concepts and results to smallholder farmers in rural areas of southern Zimbabwe. That, with the intention of increasing the farmers' awareness on agricultural models and obtaining feedback on how to improve our way of designing agricultural models and communicating modelling outputs to smallholder farmers. Smallholder goat farmers were chosen as target group. Goat farming issues and potential solutions were investigated with farmers, through the use of the livestock farming model Dynmod. In doing so, the framework of a workshop/focus group was designed to guide the non-modelling expert into this discipline, from the very basic to its application. The learning path outlined include PLAR (Participatory Learning and Action Research) key concepts, the application of which produced many qualitative insights worthy of note. Smallholder farming practices were explored. It was found that the bigger the goat herd the lower was the animal mortality rate throughout the different age/sex classes. Still, a more market-oriented attitude was found for the 'bigger' farmers. Participatory modelling simulations, based on real farming input-data communicated by the farmers, were run and collectively analysed. 99% of the farmers reported that participatory simulations were useful for their understanding on modelling. Attention was given to the communication of modelling results issue. It was found that, the older the farmer and the lower his/her level of education the better he/she preferred a model's result representation via images. Overall, farmers unanimously considered agricultural models as helpful tools to explore farming activities. The findings of this thesis captured the workshops' participants interest in receiving modelling-based advices, to explore farming decision making. The strong farmers' positive response to Dynmod and modelling in general, can lay the basis for further projects in which smallholder farmers will be assisted in their practices through simulation modelling. This, in turn, can enhance livestock productivity in semi-arid Zimbabwe and thus support the small-scale livestock keeper.

Keywords: Participatory modelling, Focus group, Learning framework, Smallholder farmers, Goat farming, Semi-arid Zimbabwe.

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[1] In Ndebele it means "stepmom".
[2] In Ndebele it means "stepdad".
[3] In Ndebele it means "thank you".

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1. Introduction

Keating & McCown (2001), after having explored the utilization of agricultural system models in the past 40 years, criticized many modelling efforts for their lack of attention to a system perspective, especially for not having engaged the stakeholders into the modelling steps. According to Matthews *et al.* (2002), who reviewed the application of simulation modelling in developing countries in smallholder farming contexts, no successful modelling applications by farmers have been found. Yet, as reported by Carberry *et al.* (2004) *"simulation modelling has struggled for relevance in real-world agriculture and for impact on farmer decision-making"*. The authors were referring to developed countries (Australia, USA, Europe). It seems that both in developed and developing countries, agricultural modelling faced difficulties in being a relevant technology in influencing farmers' decisions (Whitbread *et al.*, 2010). Both Keating & McCown (2001) and Carberry *et al.* (2004) criticized context-free model application, where research-designed models were tested under hypothetical conditions, generally without concrete references to the real-world.

A solution to that has been found in the concept of participatory modelling approach, introduced in the 1970s once the importance of involving the stakeholders in the modelling steps became more broadly recognized (Voinov & Bosquet, 2010). At this point, some modelers started working with clients and organizing workshops with stakeholders. Several papers described participatory modelling experiences that successfully influenced the farmers' way of doing agriculture (see chapter 1.4).

Inspired by these experiences, it is the intention of the present project to share modelling knowledge with smallholder goat farmers in the semi-arid southern Zimbabwe context, through participatory modelling workshops. This intention has the twofold aim of increasing the farmers' awareness on agricultural models and consequently obtaining feedback on how to improve our way of designing agricultural models and communicating modelling results to the stakeholders. The model is not the issue in itself but rather the focus is on the discussions that emerge as a consequence of the simulation process.

1.1 The smallholder farming context in the rural areas of the southern Zimbabwe

The most common way of doing agriculture in the rural areas of the southern Zimbabwe is the mixed crop–livestock system, integrating crop and livestock activities and the grazing areas' management (Homann-Kee Tui *et al.*, 2015). The typical relations across these components are: the use of crop residues as feed, the application of animal manure on the fields and the land cultivation exploiting animal draught power (Descheemaeker *et al.*, 2016). African mixed farming systems are heterogeneous in terms of land and livestock ownership, soil fertility, labour availability and farmers' attitudes (Giller *et al.*, 2011). However, a common characteristic among these systems is the multi-functionality of the animals kept. Livestock are kept not only for meat, milk and skin production but also for crop-related functions, such as ploughing and material transportation (Otte & Chilonda, 2002).

In the semi-arid regions of southern Zimbabwe, smallholder farmers are facing serious challenges in obtaining household food security. Low soil fertility, limited resources and highly variable rainfall contribute to create very harsh agricultural conditions (Descheemaeker *et al.*, 2018). In such a resource constrained environment, goat farming presents several advantages.

1.2 The smallholder goat farming context in semi-arid Zimbabwe

Goat farming is nowadays a widespread practice in all the regions of the world, accounting for 976 million live animals, with more than 300 different breeds (FAO, 2015). The main reasons for a such widespread diffusion are: goats' adaptability to different environments, high reproduction rate, small size and low nutritional requirements (Aziz, 2010). The large majority of the goats are farmed in Africa and Asia especially in the smaller farms, contributing to provide food and economic security to the household (Aziz, 2010).

More than 85% of Zimbabwean smallholder farmers own small ruminants (van Rooyen *et al.*, 2013). Goat farming plays an important role in the smallholder farming communities providing meat, milk, manure, skins and cash income (Mhlanga *et al.*, 2018). Moreover, as noted by Simela & Merkel (2008), goats happen to be deeply involved into the socio-cultural and religious traditions of the rural population; owning goats is for the farmer a way of showing to the village his/her prestige (**Appendix 1**). Besides the socio-cultural importance, several publications (Dube *et al.*, 2014; Homann-Kee Tui & van Rooyen, 2006; van Rooyen *et al.*, 2013) recognized a common tendency among the Zimbabwean smallholder farmers: goats are perceived as "small discrete bundles of cash", ready to be sold in case of needs. The average market price for a medium quality goat is 35-50 US$; the cash earned from the sales is mainly invested in food purchases, educational and medical expenses, but rarely in farming related purchases (van Rooyen *et al.*, 2013).

Even if goats represent a realistic option for sustaining smallholder farming in a resource-constrained context such as semi-arid Zimbabwe, several constraints occur. High animal mortality rate in livestock farming, achieving levels of 30% in the goat case, is one of the main weaknesses (van Rooyen *et al.*, 2013). Zimbabwe has a population of three million of goats, raised in communal areas under extensive farming conditions (Mhlanga *et al.*, 2018). With mortality rates at about 30%, every year 900,000 goats are lost. This is mainly a consequence of improper herd management in terms of animal health, animal nutrition and animal housing (Homann-Kee Tui & van Rooyen, 2006). Based on the participatory survey conducted by Homann-Kee Tui & van Rooyen (2006) in southern Zimbabwe, three quarters of the farmers reported frequent goat diseases problems both during the dry and the wet season. Most of the diseases could have been prevented and/or treated by the farmers if there was proper access to farming knowledge and diagnosis/prevention information about the most common illnesses. Moreover, during the dry season most farmers experienced severe animal feed shortages; that evolved inevitably in animal malnutrition increasing the dry season mortality rate. Many farmers indicated that they could have used different feed resources, but they did not manage to preserve it due to the lack of knowledge in processing and storing (Dube *et al.*, 2014). The lack of governmental and institutional information channels, not properly assisting the smallholder farmer decisions, appears as one of the main goat farming weaknesses in the rural areas of southern Zimbabwe (Dube *et al.*, 2014).

Another crucial constraint affecting goat farming in the semi-arid Zimbabwe is a too weak goat market. According to Homann-Kee Tui *et al.* (2007), goat markets happen to be underdeveloped, the infrastructures are inadequate and more than often high transaction costs and low prices for goats occur. Formal market facilities result to be better established for cattle trading. Farmers regularly have no alternatives than trading their goats at the farm gate at very low prices. Thus, they have very little encouragement in improving their goat management practices.

In this complicated context, simulation modelling could be useful in supporting farmers to design, assess and implement innovative and sustainable farming systems (Le Gal *et al.*, 2011). Many livestock simulation models have been created until now: Ruminant, LivSim, Grazplan, Dynmod, GLEAM, IMPACT-HHM, IAT, Grazplan and APSFARM, just to name a few (Jones *et al.*, 2016). They differ between themselves mainly in terms of the scale of analysis (local, regional, national, etc.) and the level of complexity of the model itself. Higher complexity level brings higher level of accuracy in the model prediction but also a greater data demand, in terms of inputs/parameters (Whitbread *et al.*, 2010).

This thesis focused on the use of the Dynmod model, a relatively simple demographic livestock Excel spreadsheet developed by CIRAD (French Agricultural Research Centre for International Development) and ILRI (International Livestock Research Institute) in 2007. The use of simple models, such as Dynmod, could be an appropriate way to evaluate ex-ante the effect of different farming implementation at farm level with farmers (Andrieu *&* Nogueira, 2010). Dynmod presents several advantages. First of all, it is relatively simple, thus it is not very data demanding. Considering the data-scarce environment on small ruminants farming systems of Sub-Saharan Africa (Tedeschi *et al.*, 2011), Dynmod was an adequate compromise. Moreover, it is quick to run and therefore it is possible to produce simulations exploring the results with farmers 'in the field', capturing effects of different management practices on the goat herd population dynamics.

1.3 The Dynmod model

Dynmod was originally designed for educational purposes; the underlying demographical model is consequently simplified. Even if much more complex, accurate and elaborated research-oriented models have been designed (Jones *et al.*, 2016, Le Gal *et al.*, 2011), several experiences showed that simple models, such as Dynmod, had an impact on farmers' knowledge and practises (Sempore *et al.*, 2015). This could be useful in many applications, such as livestock productivity estimation and the exploration of scenarios in development projects (Lesnoff, 2013).

According to the Dynmod User's manual (Lesnoff, 2013), the model simulates livestock population size dynamics and consequently estimates live weight, meat, milk, skin, hides and manure production. Rough estimations of the feeding requirements in dry matter are also part of the results. Dynmod is a deterministic model in which no seasonal variations happen, the parameters are not constrained by population density, primary resources (feed, water, etc.) or economic variables (livestock prices, market offer/demand, etc.). Reproduction is assumed to be dispersed all over the year. The time-step used in the calculations is one month. In the model, livestock population is divided by sex (male and female) and age classes (juveniles, sub-adults and adults). The age class' length must be defined according to the livestock species considered and the farming management. Only adult female individuals are considered to be reproductive. In each age class, livestock can survive or be removed through natural death (illness, predator, etc.) or offtake (animal selling or culling/slathering). Deaths are simulated through mortality rates. Offtakes are simulated not only through offtake rates; in fact animals surviving until the end of the adult stage are automatically removed through culling (see **Figure 1**). Further details can be found in the Dynmod User's Manual (Lesnoff, 2013) provided by CIRAD and ILRI. Dynmod is an open source model.

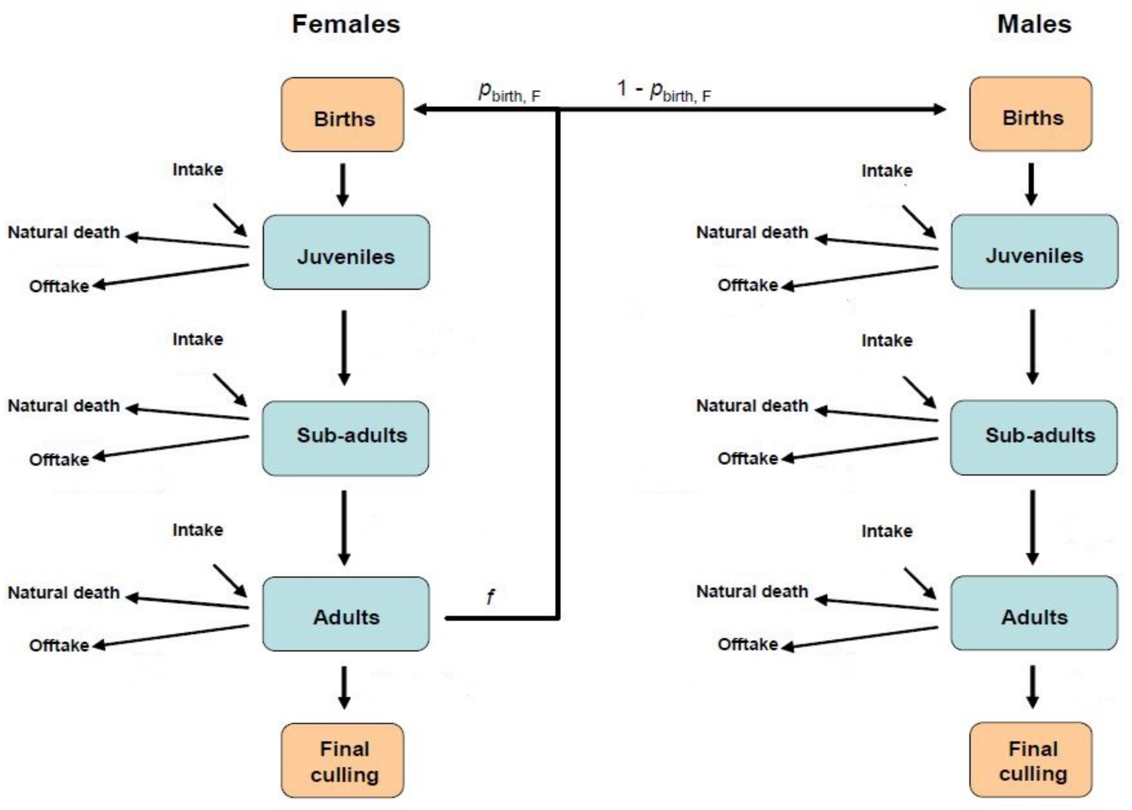

Figure 1: *The Dynmod model's structure (Lesnoff, 2013).*

Keeping in mind that most of the Zimbabwean smallholder farmers perceive goats as small discrete bundles of cash ready to be sold in case of needs (Dube *et al.*, 2014), the fact that Dynmod simulates goat herd population dynamics happened to be crucial. It was indeed expected (see chapter 1.1 and 1.2) that farmers were more interested in the number of live animals and the goat herd dynamics rather than other aspects such as the milk/meat productions (which, even if part of the Dynmod outputs, they are not the focus point of the model). Moreover, the mentioned Dynmod simplicity, which is a consequence of its original educational design, worked in favour of the study aim of increasing the farmers' awareness on agricultural models.

However, Dynmod was not the focus of this research, nor was its calibration, potential application or improvement. Rather, the focus was on the discussions that rose as a consequence of the simulation process. In such a perspective, Dynmod happened to be a relatively easy model example that allowed people to be introduced on agricultural modelling and its benefits.

1.4 Why a participatory approach is necessary

"For decades prior [to the 1970s], *scientists had been carrying out their studies among themselves, modelers analysed the systems that were of interest to them, and software developers produced algorithms and programs that they believed would do the best job. Indeed, they were the experts; they knew better how the systems work and tended not to question why somebody else should decide what was needed to solve important problems."*

Quote 1: *(Voinov & Bousquet, 2010)*

Chapter 1.2 highlighted the strengths and weaknesses of the smallholder goat farming systems in southern Zimbabwe, chapter 1.3 exposed a potential solution in the form of a model, Dynmod. But what is the best way to apply the modelling tool? As mentioned, most of the research-designed models have been tested under hypothetical conditions, generally without concrete references to the real farming context. A solution to bridge the gap between real-farming situations and modelling efforts could be found in the participatory approach.

The concept of participatory approach in modelling science was firstly introduced by Forrester in 1961, aiming to involve clients into the process of model design. In the 1970s the central role of the clients in the modelling steps became more broadly recognized; modelers started working with individual clients and organizing workshops with stakeholders more often (Voinov & Bosquet, 2010).

When it comes to agriculture, Le Gal *et al.* (2011) reviewed different methodologies to assist the farmers' implementation of new technologies, in which modelling is a crucial stage. Two different approaches were depicted, the linear and the interactive/participative innovation processes. The *linear innovation process* mainly involves the use of existing knowledge and the use of modelling tools (generally based on generic properties of the object/system to be designed) from the researchers to the farmers through the local advisors. This approach did not enable successful adoption of the innovations proposed in the past, especially in developing countries (Matthews *et al.*, 2002; Sumberg, 2005; Whitbread *et al.*, 2010). On the other hand, the *interactive/participative innovation process* changes the roles of researchers, advisors and farmers in the farming innovation design process. In such a perspective, farmers are not anymore, a 'passive audience' of the innovation design. Researchers both work apart from and in interaction with farmers and advisors, in designing innovative production systems (see **Figure 2**). In that perspective, models are essential to evaluate ex-ante the interactions between the farm's components and the impact of new technologies or alternative farming management approaches. The concept of participative innovation design gives a crucial role to the stakeholder participation. Participation facilitates the design and implementation of innovations by considering the needs, limitations and knowledge of farmers in the system under study.

A good example of how the interactive/participative innovation process have been pursued, in order to increase the interactions between researchers and stakeholders, is the DEED (Describe, Explain, Explore, Design) approach developed by Giller *et al.* (2008). The essence of this approach is the combination of ex-ante trade-off analysis and on-farm trials in iterative learning cycles with farmers. Where DEED was applied, it produced useful insights to re-design farm systems and introducing new technologies, especially in developing countries (Descheemaeker *et al.*, 2019; Falconnier *et al.*, 2017; Ronner *et al.*, 2019; Rufino *et al.*, 2011; Tittonell *et al.*, 2009).

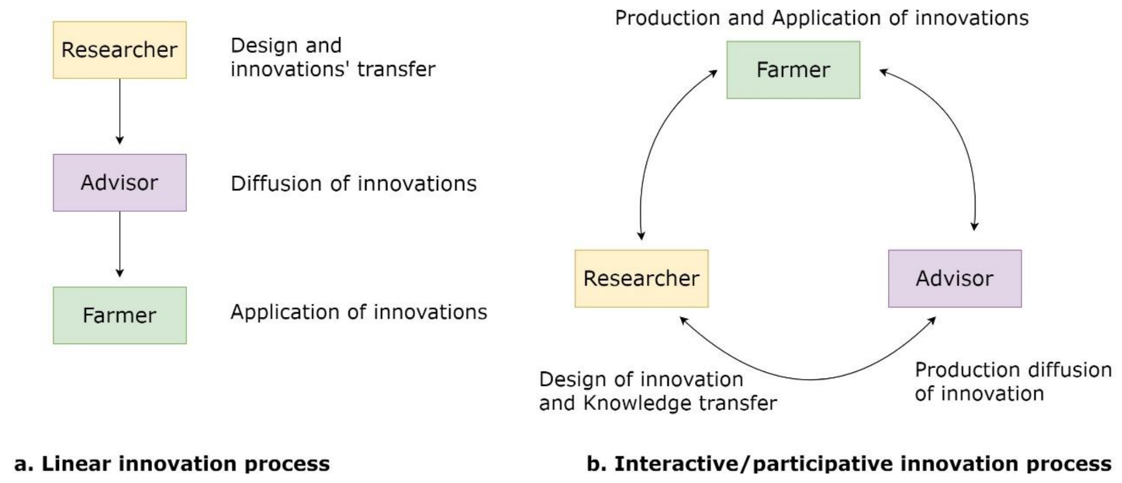

Figure 2: *Schematic representation of the linear and interactive innovation processes. The role of farmers, advisors and researchers in the processes are shown (Inspired by Le Gal et al., 2011).*

Another good case of participatory modelling approach is FARMSCAPE (Carberry *et al.*, 2002). FARMSCAPE (Farmers, Advisers, Researchers, Monitoring, Simulation, Communication and Performance Evaluation) is an Australian project promoting the use of agricultural models to the Australian commercial farmers via participatory approaches. It was a great example where a modelling intervention with farmers, led to tangible farming management changes (Carberry *et al.*, 2002).

The same Australian modelling school reported the experience of a participatory modelling workshop in Zimbabwe (Carberry *et al.*, 2004), aiming to explore the effects of various soil fertility management practises with smallholder farmers, through the cropping system model APSIM (Agricultural Production Systems sIMulator). The researchers, initially sceptical that modelling could have been relevant to smallholder farmers, reported: *"While this approach has proved successful with commercial farmers in Australia, it was a surprise that computer simulation was apparently relevant to smallholder farmers in Zimbabwe"*. The Carberry *et al.* (2004) study also depicted the pro-active farmers' engagement into the workshop discussions: *"The farmers in this engagement were not passive participants, rather they acted as experts in their own domain, using the simulator to explore possible consequences of altered management. All the researchers left the focus meeting with the feeling that real engagement and learning had occurred."* Farmers' active engagement into the workshop, indicated that they found the 'modelling tool' meaningful and credible for the reason that the simulations were tailored on real farming scenarios. The participatory modelling approach is an effective way to achieve a tangible impact on smallholder farmers' mind and attitude toward agricultural practices (Carberry *et al.*, 2004).

Andrieu & Nogueira (2010) developed a relatively simple model with farmers in the semi-arid areas of Brazil. The purpose of the model was to evaluate the long-term effects of different farming managements on the environment. The overall aim of the study was to design a discussion support tool able to illustrate the trends and potential impacts of current management practices to farmers. And therefore, teach farmers about the impact of their practices. The learning process involved many local farmers throughout the modelling stages, from the conceptualization to the model validation. As reported by the authors, *"Unlike existing sophisticated models that are intended to be predictive tools, this model acts as an intermediary between farmers and researchers to promote learning about the practices"*.

Even if the importance of involving the stakeholders in the different steps of the farming innovation design has been broadly acknowledged, there is little empirical evidence that a participatory approach can increase the application of the research outputs (Sumberg *et al.*, 2003). A combination of learning approaches were applied in this project, these methods will be discussed in chapter 2. It is the intention of the present study to evaluate the participatory methods applied in the context of the rural areas in semi-arid southern Zimbabwe.

1.5 Aim of the study and research objectives

As shown in chapter 1.4, agricultural modelling science often remained into the research sphere without having a real impact at farming level, especially when it comes to smallholder farming. Because of that, the overall aim of this study is the *dissemination of modelling concepts* (the way of scientific thinking about agricultural systems) and the *communication of modelling Dynmod outputs* to assist farmers in decision making, through participatory modelling workshops. Once that knowledge was provided, it was possible to gather farmers' feedbacks via a questionnaire in order to understand how they perceive modelling.

In order to achieve that, a participatory modelling workshop was designed. Different learning approaches were applied: lecture, division in subgroups, discussion groups, learning exercises, role plays and case studies (Pretty *et al.*, 1995). Moreover, the application of the PLAR (Participatory Learning and Action Research) key concepts, allowed the combination of qualitative and quantitative insights (Defoer, 2002). These aspects, which will be explained in chapter 2, can be resumed in the following methodological objective:

1. To design the framework of the participatory modelling workshop

As presented in chapter 1.1, goat farming in semi-arid southern Zimbabwe is a promising way to sustain smallholder farming development. However, several constraints are present. High goat mortality rate seems to be the main productivity constraint, but it is not the only problem. The lack of governmental/institutional information about good farming practices followed by a too weak goat market, affect the overall farmers' performance and perspective. To address these problems, a further understanding of the current goat farming system is required.

Therefore, the second research objective is formulated as:

2. To describe the smallholder farming system in the rural areas of semi-arid Zimbabwe
$Hyp_{2.1}$: Most of the farmers do not perceive goat farming as a profitable activity

In a complex agricultural system, such as goat farming, modelling helps to understand the system behaviour and to assist farmer's decision making. The Dynmod model, as presented in chapter 1.3, provides livestock demographic analysis insights useful for many applications, such as productivity estimation or exploration of scenarios (introduction of new technologies, different farming management techniques) in development projects. It was hypothesised that most of the farmers (especially in developing countries), due to their lack of computer knowledge, do not have any idea about the potential of agricultural modelling in assisting their decision. Hence, it was the intention of this study to share with smallholder farmers the basics of modelling, in order to let them be aware about the modelling tool. Moreover, through participatory Dynmod modelling sessions, it was shown how a model can practically underpin decision making in goat farming. Another important issue kept into account was the communication of modelling results. In fact, once an agricultural model output is produced, it has to be communicated to the farmer. In that viewpoint most of the models lack an interface (agriculture-related model efforts are mainly oriented on the mathematics of the model itself). There is indeed a lack of a communication model/guidelines regarding agricultural communication and the relation between scientific and indigenous knowledge (Cannon *et al.*, 2016). Thus, this study aimed to investigate how to present efficiently a model output to the Zimbabwean smallholder goat farmers (efficiently intended as finding the right common language that allows the modeler to present results and the farmer to comprehend them). According to Tullis (1981) different ways of presenting model results are possible: narrative (words and phrases), structured (tabular format), graphic/chart, use of colours and use of images to support the user comprehension. These ways were presented to the workshop's participants and their feedbacks were gathered.

Once a common knowledge ground was established, this study aimed to gather the smallholder farmers' opinions on the agricultural modelling role in assisting farming practises, on the Dynmod model and on the communication of models' results. This was useful to understand the farmers' viewpoint on modelling and how simulation tools are perceived by them. Moreover, the information gained could lead to adaptation and improvements on the way of modelling in further projects.

Therefore, the third research objective is formulated as:

3. To describe the farmers' perception of agricultural modelling in assisting their farming practices

$Hyp_{3.1}$: The big majority of the farmers do not have prior knowledge about agricultural modelling

The objectives just depicted were approached in the context of participatory modelling workshops, organized in several villages in rural areas of southern Zimbabwe. As exposed in chapter 1.4, participatory modelling approach is a relatively new methodology introduced to overcome the mentioned gap between modelers and farmers. Therefore, different participatory practises (*division in sub-groups, discussion sessions, learning games, participatory modelling)* were performed and evaluated. Qualitative aspects (e.g. conceptual models drawn by farmers, information gained from the discussion sessions, the farmers' reaction to specific topics, the farmers' attitude, etc.) provided information that strengthens quantitative assessments collected via the questionnaires. Thus, it is the intention of this study to evaluate the methodologies applied during the workshops. Therefore, the fourth research objective is formulated as :

4. To evaluate the participatory approaches applied

2. Methodology

In order to achieve the research objectives presented in chapter 1.5, several participatory modelling workshops were organized. At the end of each workshop, farmers were asked to fill out a questionnaire in order to gather information on their goat farming background and their impressions and opinions on the information delivered during the workshop itself (see **Figure 3**).

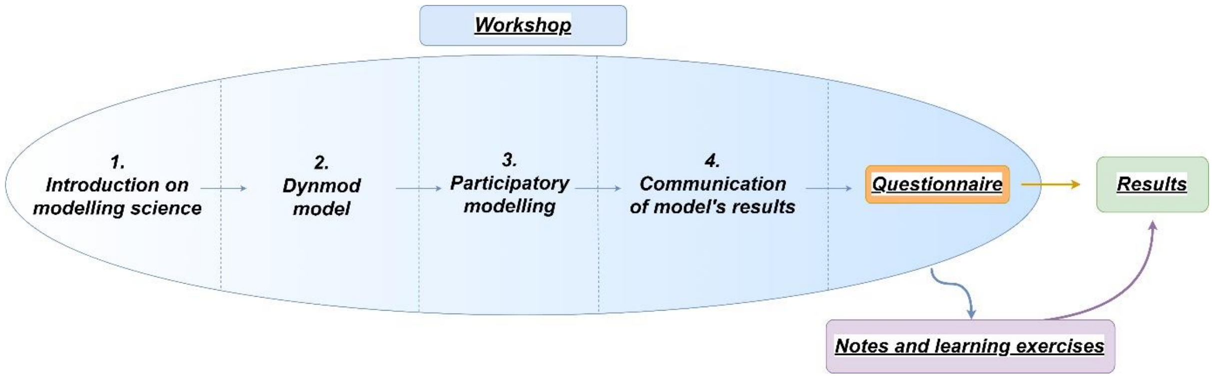

Figure 3: *Thesis project framework.*

2.1 The workshop – RO1[4]

The definition of workshop is: "a brief intensive educational program for a relatively small group of people that focuses especially on techniques and skills in a particular field" (Merriam Webster, 2019). Keeping in mind that the overall thesis aim was the dissemination of modelling concepts and the communication of modelling outputs, the workshop/focus group framework happened to be the best arena for this purpose. Focus group discussion is indeed a technique where a group of individuals has assembled to discuss a specific issue, aiming to gather personal experiences, beliefs, perceptions and attitudes of the participants, through a moderated interaction (Nyumba *et al.*, 2018). As reported in chapter 1.4, participatory modelling approaches were effective in communicating modelling science to non-modelling experts, both in developed and in developing countries. Thus, the combination of the workshop framework and the participatory modelling approach key-concepts, culminated in the establishment of several participatory modelling workshops with smallholder goat farmers in the Gwanda district in southern Zimbabwe. The workshop was titled: *"In goat we trust – The potential of goat farming in the communal areas"*. A total of seven workshops were organized.

The location

Gwanda district, located in the Matabeleland South Province (see **Figure 4**), was selected as a promising location for the following reasons (Dube *et al.*, 2014):

- Increasing goat market in the area;
- Several studies were conducted here thus, many demographical, social, economic and agricultural data are available;
- Gwanda's people were used to collaborate with researchers and NGOs (workshops, interviews);

[4] RO1 stands for "Research Objective 1", referring to the first research objective presented in chapter 1.5.

- Many experts from MRI [5](Matopos Research Institute) were familiar with the area.

Gwanda district has a population of roughly 115,000 people of which 98% live in rural villages (ZIMSTAT, 2014). The Gwanda province, Matebeland South, experiences one of the highest poverty rates in Zimbabwe. During April 2012, the average household income was below 100 US$/month. Given that 30% of the Gwanda's households are food insecure (ZimVAC, 2013), food security represents also a problem.

Within the Gwanda area, 7 villages have been selected as promising locations for the workshops' conduction (Humbani, Pelele, Gungwe, Sengezane, Patana, Nhwali and Takaliyawa). The villages were recommended by MRI's experts.

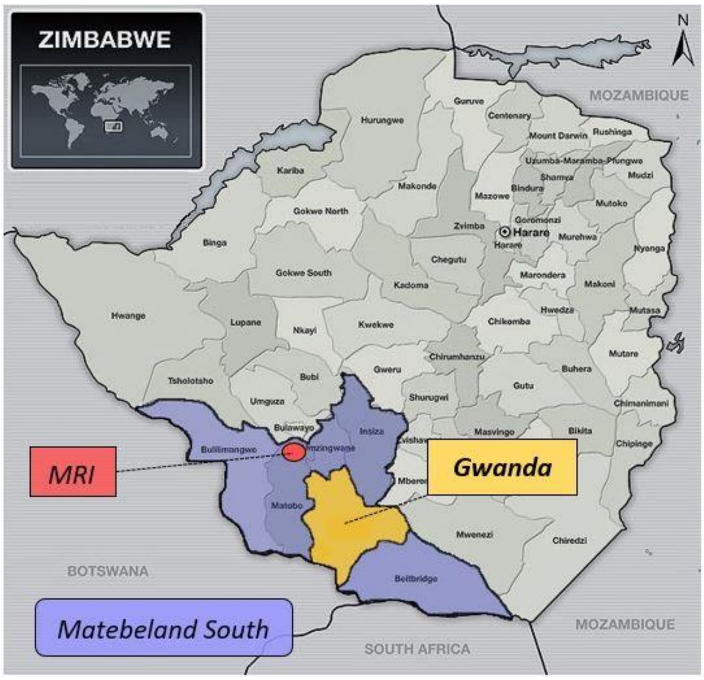

__Figure 4:__ The study site (Gwanda) and the MRI locations.

The participants

According to Dube *et al.* (2014), four smallholder goat farmer's categories can be distinguished in the Gwanda district (see **Appendix 2**). That categorization considered several characteristics, such as demographic data, assets, information sources, income, crop and livestock production. A relation between the goat herd size and the farmer's category can be found. Inspired by that, four smallholder goat farmers' classes were distinguished (F1-F2-F3-F4), in order to identify the workshop's participants (see **Table 1**).

__Table 1:__ The four smallholder farmers classes.

Farmer Category	F1 Very small	F2 Small	F3 Medium	F4 Big
Goat herd size (X)	$1 \leq X \leq 5$	$6 \leq X \leq 15$	$16 \leq X \leq 25$	$X \geq 26$

That categorisation aimed to catch the overall goat farming picture, and thus investigate the differences between the classes. The target was to gather *5 participants per category* in each session, for a total of 20 farmers per workshop.

The logistics

In a context lacking infrastructure (paved roads, communication, electricity) like the Gwanda district, the MRI expert's assistance was fundamental to lay the foundations of this project. Moreover, even if in Zimbabwe the English language is broadly spoken, in the rural areas most of the people are used to speak other local idioms (Ndebele predominantly). Aware of those challenges, the first step was the set-up of a *familiarisation round*, in order to get in touch with the area and communicate with the extension officers (the bridge between the government/institutions and the local farmers) related to

[5] MRI is the Zimbabwean research institute which hosted and facilitated the present thesis project.

the different villages. That stage was fundamental to comprehend the complex social texture of the area, communicate to the extension officers our needs and planning the logistics and mobilization for the upcoming workshop projects. Once the extension officers were informed about our initiatives, in their turn they informed the respective village heads (the political entity of the village), selected the participants (according to the criteria indicated in **Table 1**) and found the most suitable workshops' meeting place among the village possibilities.

Once the workshop activities began, a team of 4 MRI's people (including myself) with different responsibilities were selected: one driver and expert of the Gwanda district MRI's research officer (essential for mobilization and networking), two MRI's students and myself as workshop facilitator. The students were crucial in supporting the workshop activities in many ways: interpretation services from English to the local languages and vice versa, assisting farmers during the questionnaires' filling and taking notes all over the activities. As reported by the local experts, a lunch is usually provided to the farmers in that type of activities; thus, food and beverages have been brought to the villages. Cooks from the community were recruited to prepare the meal. The village head and other representative members (e.g. councillor, ward head) of the socio-political structure have also been invited to join the workshop.

The setting

Different villages brought different workshop settings. Five workshops out of seven were conducted indoors (warehouses, schools and meeting halls), while the remaining two in the open spaces. Due to the complete lack of electricity in Gwanda's rural areas, handmade flipchart "slides" were prepared as a learning tool to support farmers' comprehension (see **Appendix 3**). The workshops were conducted in English and simultaneously interpreted in the local language by the MRI team's members and/or the extension officers.

The learning structure

The papers cited in the introduction and other more "applicative manuals" on participatory methodologies (Alliance Manual, 2001; Alliance Manual, 2002; Millot & Buckley, 2013; Pretty *et al.*, 1995; Reina *et al.*, 2003), inspired and steered the design of the present participatory workshop's framework, whose structure is briefly shown in **Figure 3** and in better detail in **Table 2**. The learning structure was designed to guide the non-modelling expert into this discipline, from the very basic to its application. The learning "path" began with the analysis of the goat farming's system complexity, showing how drawing a conceptual system diagram is an effective way to approach complex systems. At that time, farmers were asked to divide in sub-groups and draw themselves their conceptual goat farming system, then presenting it to the plenary in the context of the '*draw your own goat farming system'* learning exercise. In that way the participants were deeply engaged into the conceptual model's design step. The information flow moved on the Dynmod model, its potential and its limits.

In between this and the following step, the '*stone game'* was performed as a way to explore the participants' goat farming purposes. A flipchart made up of two main categories, "own consumption" (intended as subsistence farming) and "market", with each one containing sub-categories (see **Appendix 4**) was prepared. Farmers were asked to pick up one stone from a box and place it on the sub-category that best described their way of farming goats. The main difference between the two categories lies in the market orientation. In the case of the "own consumption" category, there was little to no market orientation while the other category indicated a mere market-oriented drive. Once all the workshop's participants expressed their opinion, the stone game's outcome were collectively analysed in the context of an open group discussion.

After that, the workshop moved on the participatory modelling step. One or more farmers each workshop was/were asked to communicate to the facilitator some details about the goat herd (number of animals per age/sex class and farming management adopted). Those numbers were 'fed' to Dynmod. After that, the impact of different scenarios on the flock dynamics were explored. Four goat farming interventions were explored: deworming, medication, vaccination and building a shelter. The main reason behind the choice of these particular interventions lies in the fact that they represented real problems that most of the smallholder farmers were facing in their daily goat farming practises. These interventions were recommended by MRI's experts, extension officers and local veterinarians. Moreover, these scenarios could be captured efficiently by Dynmod altering the mortality rate parameter. In that perspective, it was assumed that the application of these innovations affected the goats' mortality rate by reducing it. Based on the MRI's expert and the local veterinary services recommendations, the Dynmod mortality rate was reduced by 2.5 percentage points (evenly for the goats' age/sex classes) for every innovation scenario. Hence, the baseline and the innovation scenario simulations were run over five years and compared. The results (in form of line charts) were then copied from the computer to the flipchart, explained and collectively analysed. Consequently, an open group discussion was staged (see **Figure 5**).

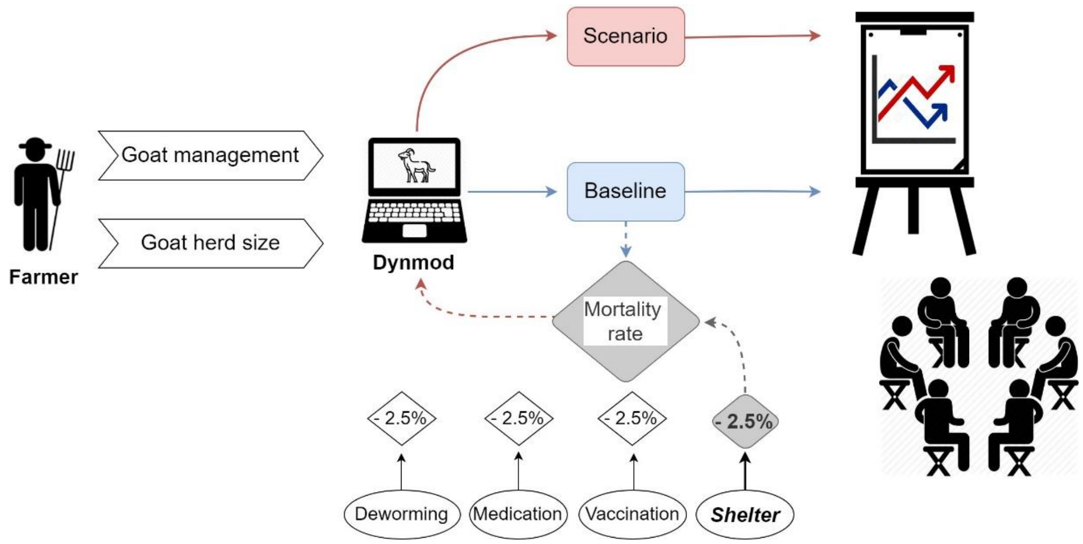

Figure 5: *Participatory modelling framework in the case of the 'building a shelter' scenario.*

After the results analysis, the last workshop step was the analysis of different ways of showing a model result. In this regard, the same model output was presented in five different ways: narrative, structured (tabular format), graphic (line and column chart) and images. Via the questionnaire it was asked to the farmers to rank these categories on a scale from 1 to 5, where 1 indicated the most comprehensible model's result representation while 5 the less (see **Appendix 5**). The last workshop stage was the filling of the questionnaire.

The learning shape

In order to keep the trainers' interest active on the modelling subject, a combination of learning approaches was undertaken (Pretty *et al.*, 1995). Several methods of instruction have been used during the workshop:

- *Lectures:* the traditional teaching approach based on the communication of a prepared talk. Assistance with visual aids (flipchart slides) were used to guide the participants into the new topic;

- *Division in subgroups:* creation of small ‘buzz-groups’ in order to discuss specific aspects;

- *Discussion groups and learning exercises:* the subgroups created were asked to discuss about a topic and/or to do a learning exercise, such as ‘draw your own goat farming system’. After the discussion, one group-member reported the group’s findings to the plenary;

- *Brainstorming and collecting ideas:* in the context of the ‘stone game’, ideas and feedback were gathered very quickly. After that, results were further discussed and evaluated.

- *Role plays and Case Studies:* participants used their own experience to play a real-life situation, which was mimicked in a model simulation. The presentation and the analysis of a scenario that has happened or could happen, increased the participants’ confidence in the subject delivered.

Both the *learning structure* and *the learning shape* just described are shown in **Table 2**.

Table 2: *Workshop Structure.*

Main Section	*Sub-Section*	*Aim*
Workshop opening	Village head opening	Welcome from the locals and collective prayer
	Personal Introduction of the Facilitator (me)	Brief story of me and my thesis.
	Workshop Expectation	Explain the workshop's expectation
	Objectives and schedule	//
	Who are you? round of names	Know each other, engage farmers, icebreaker.
1. Introduction on Modelling Science	Introductory *lecture*	Provide general knowledge on modelling science
	Division in sub-groups and learning exercise: draw your own goat farming system	Increase learning experience
	Role play and discussion group	Reflection on the previous exercise
	Introductory *lecture "*from conceptual to mathematical model*"*	Provide general knowledge on modelling science
Lunch break		
2. Dynmod model	Introductory *Lecture*	Provide general knowledge on Dynmod model
	Lecture on "the Dynmod's outputs"	Show the Dynmod's potential
	Brainstorming and collecting ideas, Stone game, goat farming purposes	Understand the goat farming purposes engaging the participants
3. Participatory modelling	*Role plays and Case Studies,* participatory modelling simulations	Participatory modelling simulations with farmers, based on farmers' data
	Discussion group	Open discussion on the Dynmod's results just obtained
4. Communication of modelling results	*Lecture* on the different ways of showing modelling outputs	Overview on the different ways to present a model's result
5. Questionnaire	Introduction on the questionnaire	Ensure farmers' comprehension
	Questionnaire filling	Gather farmers' feedbacks
Workshop Closing	Workshop evaluation	Open feedback from farmers on the workshop framework
	Facilitator's debrief	Conclusion of the workshop session

The questionnaire

In order to gather the farmers' feedbacks on their way of approaching goat farming and perceiving the modelling topic, a questionnaire was designed. The design process followed the three main pillars proposed by Burgess (2001): the determination of the questions to be asked, the selection of the question type and the design of the question sequence and finally the questionnaire layout. Moreover, the degree of literacy, the comprehension of the questions and the understanding of the written English language were considered. A double languages questionnaire, both in English and in Ndebele (the most spoken local idiom), was provided.

The following are the main questionnaire characteristics:

- Closed questions (Yes/no, check the box, Likert scale, rank);
- Easy and understandable questions;
- Farmers were fully assisted in dealing with incomprehension and doubts;
- Ndebele translation provided;
- The questionnaire was designed to take approximately one hour to be filled out.

Content wise, the questionnaire was composed of four main sections: the farmer's identification and farm description, background information on how goat farming is performed, feedback on the modelling information delivered and feedback on the participatory approaches exploited during the workshop. A brief overview on the questionnaire structure is presented in **Table 3** (for the full text questionnaire see **Appendix 6**).

Table 3: *The questionnaire structure.*

Main section	***Sub sections***
Farmer identification	1. Demographic information
	2. General farm description
Goat farming and management information	3. Goat herd structure
	4. Goat farming management
	5. Goat Offtakes and marketing
Modelling science	6. Modelling Science
	7. Dynmod Model
	8. How to present a model result
Participatory approach	9. Workshop evaluation
	10. Questionnaire evaluation

The notes and the learning exercises

The application of the participatory approach concepts gave life to many qualitative information risen by the several discussion group moments, the learning exercise and the case studies performed. Many times, these discussions happened in the local language. So, they have been captured, noted down and then translated in English. These notations and the information gained from the learning exercises, strengthened the quantitative assessments collected in the questionnaires and constituted a significant part of the results.

2.2 The Dynmod parameterization

Besides the theoretical introduction of the Dynmod model in the first part of the workshop, the Dynmod model was also practically applied during the participatory modelling stage simulating the impact of different farming innovations on the herd dynamics. In order to adapt the model on the study site condition, ahead of the workshops the model was parameterized. The Dynmod's parameters were taken by the following sources:

- Expert consultation (MRI, local veterinary officers).
- Parameters provided by Lesnoff & Julien (2014).
- Analysis of secondary data (annual reports);

Due to the data-scarce environment on smallholder goat farming in the study site context, the model's parameterization was mostly based on assumptions made under the indications of MRI's goat farming experts (see **Appendix 7**). However, as mentioned the main focus point of the present study was not the accuracy of the Dynmod's projections, but rather providing the workshops' participants an overview on modelling science and how it could be useful in assisting their farming decisions.

2.3 The data analysis

The big majority of the data originated from the questionnaire. The answers were coded and then analysed in Excel via descriptive analysis tools (mean, standard deviations, frequencies and percentages). Ranking questions were analysed via average ranking (the respondent's most preferred choice, ranked as 1, has the largest weight while the least preferred choice, ranked as 5, has the smallest weight). The first step of the analysis helped in finding out the nature of the data collected. Afterwards, data were presented in tables, graphs and in textual form. The non-parametric Spearman's rank correlation coefficient *(r_s)*, which provides a measure of the strength of an association between two variables (ordinal and/or continuous), was used to investigate relationships between the variables (Hauke & Kossowski, 2011). Quantitative results coming from the questionnaire are supported by more qualitative observation resulting from handwritten notes and the information gathered by the learning exercises performed with farmers.

3. Results

In this section, firstly the workshops' participants demographic characteristics and the overall workshops' attendance are analysed. After that, the focus shifts on the research objectives RO2, RO3 and RO4. Quantitative data gathered from the questionnaire, notations and the information gained from the learning exercises are exposed for each research question.

3.1 The attendance and the participants

A number of 20 farmers were expected for each of the seven villages included into the project. However, the seven workshops gathered a number of 105 people (75% of the expected). As shown in **Table 1**, four farmers' categories were identified; a number of 5 individuals per category per workshop were expected. Thus, the overall attendance was scheduled to be 35 farmers per category; however, for none of the classes the requirements were met. The F1 class experienced the lowest number of attendees in relation to the expectations, while F2 class the highest (see **Table 4**).

Table 4: *Farmers' categories attendance (X stands for the goats' herd size). The shading visually represents the farmers' distribution per workshop (row) and category (column).*

Village	**F1** $1 \le X \le 5$	**F2** $6 \le X \le 15$	**F3** $16 \le X \le 25$	**F4** ≥ 26
Humbani	*0*	*8*	*2*	*9*
Pelele	*1*	*6*	*2*	*4*
Gungwe	*6*	*7*	*0*	*1*
Sengezane	*1*	*6*	*3*	*0*
Patana	*2*	*8*	*3*	*2*
Nhwali	*1*	*3*	*5*	*8*
Takaliawa	*1*	*5*	*3*	*8*
Total	*12*	*43*	*18*	*32*

The attendees' sex was evenly distributed, nearly half of the workshops' participants were female. 78% of the attendees were between 40 and 80 years old (see **Table 5**).

Table 5: *Attendees' age distribution (X stands for age).*

Age classes	$20 \le X < 40$	$40 \le X < 60$	$60 \le X < 80$	$X \ge 80$
Number of people	*22*	*43*	*37*	*1*

A positive relation between the participants' age and the goat herd size ($r_s=0.24$, $p<0.05$) was found. The attendees' educational level is reported in **Table 6**; 46 farmers completed the high school studies. A negative relation ($r_s=-0.41$, $p<0.01$) between the participants' age and educational level was found.

Table 6: *Attendees' educational level.*

Educational Level	Elementary School	Primary School	High School	University
Number of people	*0*	*58*	*46*	*1*

A percentage of 94% of the workshops' participants answered "No" to the question "Have you ever used a computer". For the ones who said "Yes", just two of them reported to use computer to get agricultural information once a year.

3.2 Smallholder farming practices – RO2

As highlighted in the introduction, livestock farming is a common practice in Gwanda district. In fact, to the question "Where do you get most of your income from", 49% of the farmers indicated "Livestock and related products" as the main source of revenue. Although from the literature review the Gwanda district appeared as a more livestock-oriented context, compared to other areas in Zimbabwe, crop production was performed by 90% of the workshops' attendees. To the question "Which crops did you grow in the last five years", 83% answered maize, 86% sorghum, 85% leguminous crops, 45% forage crops and 30% other crops (millet, watermelon, groundnuts). 48% of the land holders owned from 0.5 to 2.9 hectares, 44% from 2.9 to 5.5 hectares and 8% of the farmers owned more than 5.5 hectares. It was found that bigger goat herd's holders owned bigger crop lands. Goats are not the only animals raised in the Gwanda area. Cattle, sheep and chicken farming were pretty common, even if 72% of cattle owners had less than 10 cows, 78% of sheep owners had less than 7 sheep and 68% of chicken owners had less than 14 chicken. Furthermore, as the goat herd size increases, farmers showed the tendency to keep bigger herds of other livestock. As mentioned, the typical way of doing agriculture in the rural areas of the southern Zimbabwe is the mixed crop–livestock system, integrating crop and livestock activities with the grazing areas' management. In fact, 85% of the workshops' attendees stated to fertilize their crop lands with goat manure.

Dividing the workshops participants' goat herd size by the number of goats died in the last 6 months (the dry season), it was possible to assess the goat mortality rate. The averaged values were not so far from the goat mortality rates exposed in the introduction, reaching its peak in the juvenile classes (22-26%) more sensitive to pest, diseases and malnutrition issues. A negative relation *(r_s=-0.39, p<0.01)* between the goat mortality and the herd size was found, showing that the bigger is the goat herd the lower is the mortality rate throughout the different age/sex classes. That is noticeable from **Figure 6** in which the mortality rate becomes lower as the goat herd size progresses. In that perspective the F1 farmers class experienced the highest values of goat mortality, while the F4 the lowest.

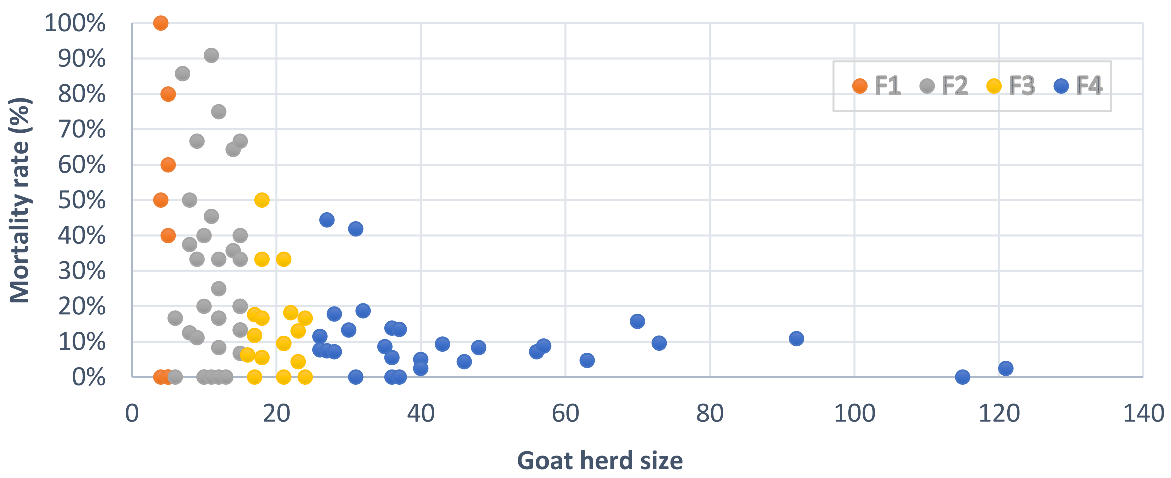

Figure 6: *Relation between the dry season mortality and the goat herd size (the farmer classes are reported).*

To the Question "What are the major causes of mortalities in your herd", 38% of the farmers indicated *diseases* as the main mortality reason, followed by *predation* (32%), *starvation/malnutrition* (26%) and *water availability* (4%). The first two are mainly a consequence of improper herd management in terms of animal housing. In fact, more than 70% of the workshops' participants reported to keep goats in *free range* systems during the day and in *open kraal* (fence) during the night. These do not seem to be the best housing systems to prevent diseases (both in the dry and the wet season) and predation. The starvation and malnutrition issues were confirmed by the fact that 37% of the farmers involved in the survey claimed that their goats do not have enough grazing areas. Forages, legumes, cereal straws and garden garbage were indicated as the main supplementary feed utilized. 14% of the farmers stated to use commercial feeds during the dry season. The water availability issue has never been raised during the discussions. Some of the farmers' feedbacks were associated to the respective goat herd size and so to the class (**Table 1**) they belonged to. Therefore, it was possible to identify some trends and patterns. As the goat herd size increases, farmers reported not having enough grazing areas. In this regard, 5% of the F3 farmers and 8% of the F4 stated to fill this lack through the use of commercial feeds. That leads to lower levels of starvation and malnutrition issues compared to the F1 and F2 farmers. On the other hand, predation seemed to trouble F4 farmers more than the other classes, probably due to the fact that the mobilization and management of bigger herds could be more critical against predators. The problem of diseases turned out to be stronger for the F1, F2 and F3 classes compared to the F4 class, probably because of latter's higher levels of medications and vaccinations, a better animal management and thus a greater goats welfare. In fact, often the discussions showed the more market-oriented attitude of the bigger farmers, compared to smaller goat owners, and so their major effort in improving the farming practices (animal nutrition, housing and management). Even if the large majority of the workshops' attendees stated to fertilize the crop lands with goat manure, as the goat herd size increases, fewer farmers showed the tendency to pursue this practice (**Table 7**).

Table 7: *Farming management and causes of mortality per farmer class. The shading visually represents the farmers' distribution in the different areas of concern.*

Question	Do the goats have enough grazing?	Do you use commercial feeds?	Do you fertilize the field with goat manure?	What is the main cause of mortality in your herd?		
Answer	Yes	Yes	Yes	Diseases	Starvation/malnutrition	Predation
F1 class	*82%*	*1%*	*89%*	*40%*	*30%*	*30%*
F2 class	*63%*	*0%*	*85%*	*50%*	*18%*	*29%*
F3 class	*60%*	*5%*	*84%*	*50%*	*21%*	*29%*
F4 class	*56%*	*8%*	*79%*	*35%*	*22%*	*39%*

As mentioned, one of the main goat farming concerns relates to a weak market, affecting the overall farming system performance and perspective. According to the farmers' feedback, almost half of the goats sold in the last six months were male adults, followed by the female adults class (29%). Over the 105 farmers gathered in the workshops, 40 reported they did not sell any goat in the last six months. A positive correlation between the goat herd size and sales has been found ($r_s=0.38$, $p<0.01$), showing a more market-oriented attitude for the F4 category. In this category, half of the offtake rates (the number of goats sold divided by the goat herd size) lies in between 13-24%. The average selling prices (and its standard deviation) reported by the respondents were 54 ± 23 US$ for the adult goat male and 49 ± 19 US$ for the adult female individuals.

In the smallholder farming systems of the southern Zimbabwe, goats are perceived as "small discrete bundles of cash", ready to be sold in case of needs. That was confirmed during the several stone games performed (see **Figure 7)**. Most of the farmers in the Nhwali village, did not perceive goat farming as a profitable activity but more as an 'economic insurance' (food purchases, educational and medical expenses). The discussions sometimes showed a lack of enthusiasm, from the farmers, to invest more time and energy in improving their goat farming practises, which is probably due to the market constraints discussed.

Figure 7: *The stone game result from the Nhwali workshop.*

The others six villages, in which the workshops were conducted, showed similar stone game outcomes which are in line with hypothesis 2.1. Few examples of more market-oriented goat farming systems came from the workshops that gathered more F3 and F4 farmers, Humbani and Takaliyawa villages (**Table 8**).

Table 8: *The numbers indicate the farmers' feedbacks throughout the workshops. The "Grand tot (%)" row shows the overall game's class distribution.*

	Own consumption			*Market*				
Village	Meat	Milk	Cash needs	Live animal	Meat	Dry meat	Milk	Cheese
Humbani	1	1	11	5	1	-	-	-
Pelele	2	-	10	1	-	-	-	-
Gungwe	2	-	12	-	-	-	-	-
Guyu	1	-	8	1	-	-	-	-
Patana	2	-	9	2	-	-	-	-
Nhwali	-	-	16	2	-	-	-	-
Takaliyawa	-	-	10	4	-	-	-	-
Grand tot (%)	***8%***	***1%***	***76%***	***14%***	***1%***	***0%***	***0%***	***0%***

In the discussions the issue of the weak goat market was often addressed. Most of the farmers (71% of the workshop's attendees), in order to have a better market access were part of goats associations. However, criticisms were often raised by the farmers about the goat associations' inactiveness in properly assisting the farmers in selling goats.

3.3 Farmers' perception on modelling – RO3

A number of 94 farmers out of the 105 involved into the workshops said "No" to the question "Did you know something about agricultural modelling before the workshop", which is in line with the hypothesis 3.1. The workshops' learning framework was indeed designed to guide the non-modelling expert into this discipline, from the very basic to its application. As mentioned, the learning path outline included PLAR key concepts, the application of which produced many qualitative insights worthy of note. One of those was the learning exercise *'draw your own goat farming system'*, during which the workshops' participants drew conceptual goat farming models based on the theoretical instructions provided by the facilitator.

A number of 28 drawings were produced by the various sub-groups of farmers formed throughout the 7 workshops. Nearly a third of the exercises gathered turned out to be in the form of descriptive texts and input/output lists (see **Figure 8a**). Most of the representations were box-and-arrow diagrams, reporting the main goat farming sub-systems and the relationships between these entities (see **Figure 8b** and **Appendix 8**).

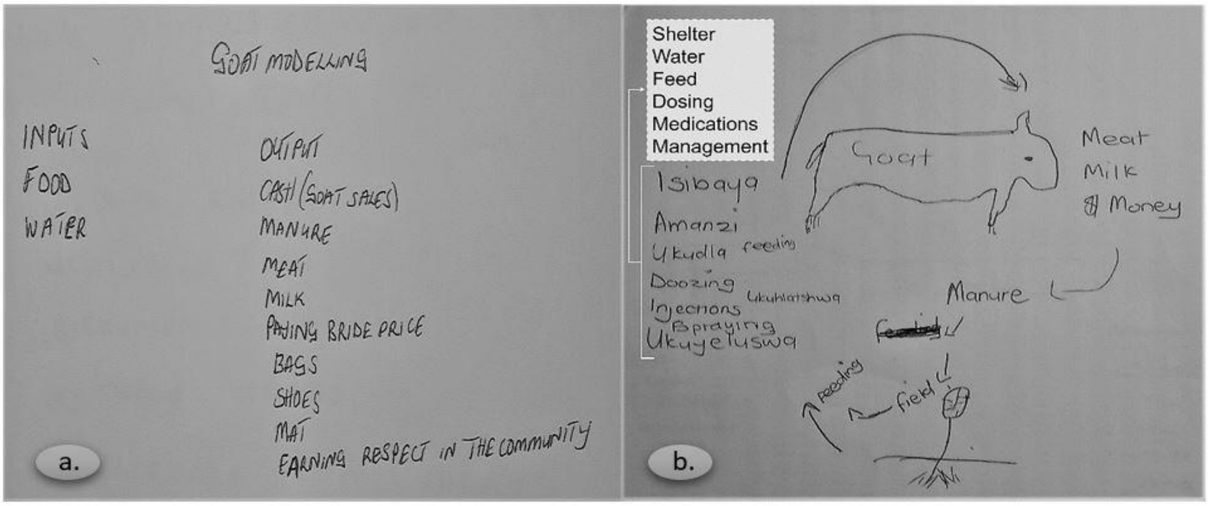

Figure 8: 'Draw your own goat farming system' exercise output from the Takaliyawa (a.) and Nhwali (b.) workshops.

The most common inputs reported in the exercises were, water and food supply, grazing areas, goat management (labour), providing a shelter; fewer people indicated medications and vaccines as goat farming inputs. The most common outputs reported were meat, milk, cash source (school fees, education, clothes, welfare), manure and hides. Some people identified the relation with the crop production component via the use of the goat manure as fertilizer. Fewer indicated horns, skin, "earning respect in the community" and "paying bride price" as goat farming outputs. The farmers' were actively engaged in the learning exercise as reported in the notes, such as: "*The farmer's response to the practice was very exquisite and all of them seemed to have understood the goat farming modelling systems"*.

As mentioned, one of the key ingredients of the learning pathway outlined, was the participatory modelling simulations. One or more farmers each workshop was/were asked to communicate to the facilitator some details about their goat herd (number of animals per age/sex class and farming management adopted); those numbers were 'fed' to Dynmod and different simulations were performed and collectively analysed (see **Appendix 9**). Given that most of the workshops' participants reported to keep goats in free range systems during the day and in open kraal (fence) during the night, the main scenario simulated was 'building a shelter'; thus, reducing by 2.5 percentage points the goats mortality parameters in Dynmod (**Figure 9**).

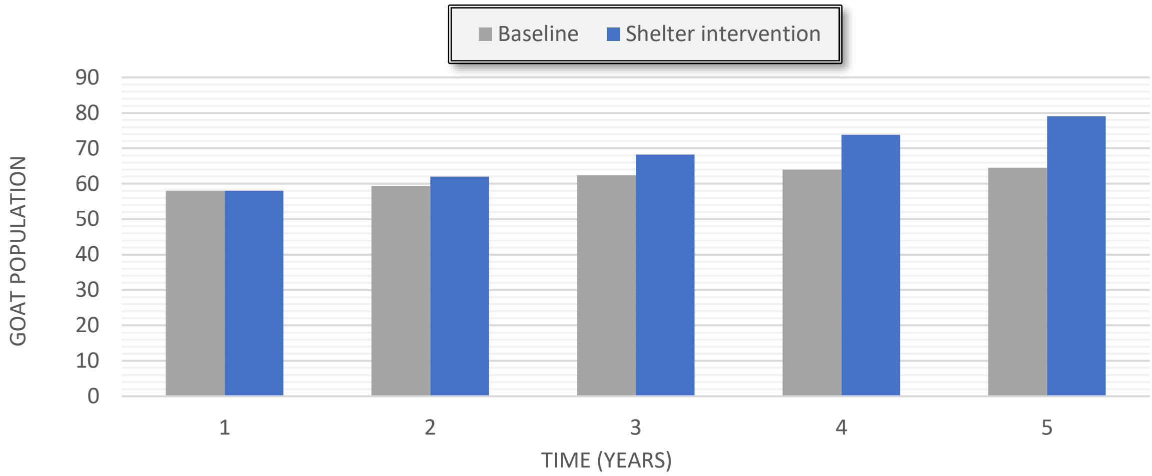

Figure 91: *Comparison of the shelter intervention and the baseline scenario. The simulation was based on the farming inputs communicated by the farmer.*

98% of the workshops' attendees answered "Yes" to the question "Do you understand the importance of agricultural modelling in helping farmers", further detecting "Predict herd performance" and "Simulate catastrophic events (e.g. drought)" as the main goat modelling advantages. About half of the farmers indicated "Calculate the income" and "Explore investment opportunities" as goat modelling benefits (see **Table 9**). In this regard, differences among the farmer classes were observed. It came out that as the goat herd size progresses, farmers were more inclined to consider "Explore investment opportunities" as a modelling advantage (27% of the F1 farmers, 41% of the F2 farmers, 56% of the F3 farmers and 59% of the F4 farmers). This seems to confirm that the larger is the goat herd size the more the owner had a market-oriented attitude. The other responses to the question did not show any particular trend among the farmers classes.

Table 9: *the farmers' opinion on the main goat modelling advantages.*

Question	What are in your opinion the main advantages of goat modelling?			
Possible Answers	*Predict herd performance*	*Simulate catastrophic events (e.g. drought)*	*Calculate the income*	*Explore investment opportunities*
Frequency (%)	73%	70%	56%	49%

Attention was given to the communication of modelling results issue. Most of the farmers (24%) responded positively to the result representation via images while 17% of the farmers appreciated the tabular one. A negative relation (r_s=-0.34, $p<0.01$) between the level of education and the representation via images was found, indicating that the lower the education level the higher is the interest toward a model result presentation via images. Moreover, the respondent's age and his/her interest for the result presentation via images were positively related (r_s=0.26, $p<0.01$). Merging this information, the older the farmer and the lower his/her level of education the more he/she is prone to appreciate a model's result representation via images. The opposite trend was found for the graphic representations (line and column chart). In this case the younger the farmers and the higher his/her level of education the more he/she is inclined to grasp a graphic way to show a model result. The narrative and the tabular way of showing a model result did not show any significant relations to other variables (see **Table 10**).

Table 10: *Results from the "How to show a model result" section and Spearman coefficient (Ns means non-significant).*

Type of representation	Average Ranking (%)	*Spearman Coefficient (p<0.05)* Age	Level of education
Images	24%	*0.26*	*-0.34*
Chart Column	22%	*-0.26*	*0.28*
Narrative	19%	*Ns*	*Ns*
Chart Line	17%	*-0.25*	*0.24*
Table	17%	*Ns*	*Ns*

99% of the attendees said "Yes" to the question "Would you like in the future, to have modelling advices before any goat farming change", further they answered unanimously "Yes" to the question "Do you think that agricultural models, such as Dynmod, could help you in your goat farming activities".

3.4 Participatory approaches practices – RO4

The last part of the questionnaire was intended to investigate the farmers' perception on the participatory approaches applied. Likert-scale questions were used to explore the workshops participants' appreciation degree towards the different practices. 92% of the farmers said, "I very enjoyed it" to the questions: "How much did you enjoy the exercises done (e.g. draw your conceptual model)" and "How much did you enjoyed the participatory modelling session", showing that these practices were effective ways to approach the modelling topic. It was possible to notice a very active farmers' involvement in these activities. Participatory approaches were interspersed by lecture-style teaching, based on the communication of a prepared talk by the facilitator. In this regard, 92% of the farmers reported "I very enjoyed it" and 8% "I enjoyed it". Assistance with handmade flipchart slides were provided to guide the farmers in the subject; for 98% of them it was useful in supporting their understanding. Most of the farmers were noting down the slides' key concepts on their notebooks. On the division in sub-groups 90% of the workshops' attendees reported "I very enjoyed it" while 10% "I enjoyed it". Farmers were prone to work in group. Fervent group dynamics were observed in most of the cases. The participatory modelling session was crucial to apply the theoretical concepts proposed to the farmers; 99% of the workshops' participants claimed it was useful to their understanding. Farmers were pro-active and willing to participate in that step. Many times, we were forced to break up the modelling sessions due to time restrictions while farmers were claiming to continue. After each modelling simulation session (usually two per workshop), farmers raised many questions demonstrating interest and curiosity in the topic. The overall farmers' opinion on the workshops were strongly positive, 90% reported "I very enjoyed it" while 10% reported "I enjoyed it". Further they answered unanimously "yes" to the questions: "Would you like to attend again, in the future, this workshop" and "Are you willing to explain what you have learned today to other farmers not present (to the workshop)" (**Table 11**).

***Table 11:** Workshops' evaluation based on the questionnaires' feedbacks.*

	What is your overall opinion about the workshop?	How much did you enjoy the talk/lesson from the facilitator ?	How much did you enjoy the exercises done (such as "draw your conceptual model")?	How much did you enjoy the participatory modelling session?	How much did you enjoy the division in sub-groups?
I very enjoyed it	**90%**	**92%**	**92%**	**92%**	**90%**
I enjoyed it	**10%**	**8%**	**8%**	**8%**	**10%**
I did not enjoy it a lot					
I did not like it at all					

	Were the flipcharts learning useful to your understanding?	Were the participatory modelling session useful to your understanding of modelling?	Would you like to attend again, in the future, this workshop?	Are you willing to explain what you have learned today to other farmers not present?
Yes	**98%**	**99%**	**100%**	**100%**
No	**2%**	**1%**	**0%**	**0%**

The last questionnaire' question "Please give us any recommendation/suggestion on how to improve our work for the next time!", was intended to gain suggestions and spontaneous proposals from the farmers. The answers were categorized in three classes, "thanks", "complaints" and "looking further". The first class met 71% of the feedbacks, while the second and the third, 11% and 18% respectively (for the full text answers of the categories "complaints" and "looking further", see **Appendix 10**).

4. Discussion

4.1 The workshop

Were the smallholder farmers the best target group to disseminate modelling concepts and communicate modelling outputs?

The project aim was to investigate goat farming issues and potential solutions, through simulation modelling, directly with the smallholder farmers. However, many players (such as research institutions, NGOs, policymakers, extension officers, farmers) take part in the small-scale farming environment. In such a perspective, information on good farming practices are usually produced by research institutes and/or NGOs and then spread in the rural areas to the local farmers, through the extension officers' communication network (Baloch & Thapa, 2018). Hence, smallholder farmers come into play at the very end of this linear technology transfer pathway. Thus, in this linear model, they could be considered more as the innovation implementers rather than the innovation designers, especially when it comes to complicated technologies that require high levels of education, clearly not met by the workshops' attendees. Given that 94% of the workshops' participants had never seen a computer and given that the role of the computer in modelling is crucial, it is unlikely to think that the farmers themselves would independently use Dynmod or any other agricultural model. This prompts the question, why to share such a relatively sophisticated modelling knowledge with people that do not have the skills afterwards to use it, apply it and so improve their conditions? Involving farmers in co-design projects let the researchers to develop better tailored technologies, by considering the needs, limitations and knowledge of the stakeholders in the system under study (Descheemaeker *et al.*, 2019; Falconnier *et al.,* 2017; Ronner *et al.*, 2018; Ronner *et al.*, 2019). In fact, it has been shown that the "top-down" transfer of technology approach was not very effective to promote smallholder adoption (Matthews *et al.*, 2002; Singhal & Rattine-Flaherty, 2006; Sumberg, 2005; Whitbread *et al.*, 2010). Several interactive/participative innovation processes with farmers were shown; indeed they were the pillars of the present study design. However, some differences among this study and other participatory modelling projects occurred.

The FARMSCAPE project by Carberry *et al.* (2002), placed its focus on providing modelling advices (via the APSIM model) to commercial farmers in Australia. Still, criticism was raised on the fact that APSIM was an over-sophisticated model and that the FARMSCAPE project was dealing with only the "top" farmers and thus its outcomes were irrelevant to most farmers. An important difference occurring between FARMSCAPE and the present project, lies in the fact that in the first efforts were put in training commercial agronomist, advisors and consultants in the application of the FARMSCAPE approach and thus in assisting farmers in decision making. Inspired by that, it could have been possible to train extension officers, researchers and other local players in the study site area, in the use of Dynmod to assist the smallholder farmers' decision making. However, due to time restrictions, it was no possible to undertake such an ambitious plan.

As mentioned, Falconnier *et al.* (2017) applied the DEED cycle, which follows the interactive/participative innovation principles. One of the DEED cycle's phase consists in performing ex-ante trade off analysis on the system under study. The authors esplored a wide array of farm reconfigurations options related to crops and livestock farming, working closely with farmers in southern Mali. The ex-ante analysis performed were based on the incorporation of farmers' indigenous knowledge and a context-specific representation of the farming systems considered, as the authors reported: *"farmers and researchers were able to share a common understanding of yield variability based on local knowledge and statistical analysis of the trials"*. The application of a cyclical combination of participatory approaches, on-farm trials and ex-ante analysis fostered both farmers and researchers to generate innovative farm systems, able to improve farm income without compromising food self-sufficiency (Descheemaeker *et al.*, 2019). In such a perspective, the implementation of on-farm experiments based on Dynmod trade off analysis, would have been a great opportunity to produce more insights on the farmer's perception of the role of modelling in assisting farming decisions.

Yet, Ronner *et al.* (2018) explored farm-level opportunities and trade-offs for climbing bean cultivation in Uganda, through focus groups, on-farm experiments and ex-ante analysis. Likewise to the present project, the authors adopted a relatively simple-to-use model, in order to enable participatory analysis of the outcomes with smallholder farmers in the co-design process. The approach undertook, thanks to the implementation of the farmer's feedback, allowed the generation and selection of relevant farming techniques, extending the basket of options for climbing bean cultivation (Ronner *et al.*, 2019).

Over the past decade the heterogeneity of smallholder farms and farming systems in sub-Saharan Africa has been investigated. In such a context rich in diversity, tailoring new context-specific farming options, improves their effectiveness and uptake potential from smallholder farmers (Descheemaeker *et al.*, 2019). In that viewpoint, the firm farmers' positive response to Dynmod and agricultural modelling in general, could lay the basis for further projects in which smallholder goat farmers will be assisted in their practices through simulation modelling. That in order to enhance livestock productivity in semi-arid Zimbabwe and support the small-scale livestock keeper to progress.

Was the workshop medium the best arena?

The workshop framework was chosen as the medium to tackle the research objectives shown in chapter 1.5. Effort was put in designing the workshop outline as a learning path to guide the non-modelling expert into this discipline, from the very basic to its application. Given that the project focus was on stimulating farmers with new concepts and thus gather their reactions, the workshop framework happened to be a proper environment for helping people to generate and share their ideas. In fact, being early in the exploration of the impact of a topic on a group of people, the focus group approach happen to be powerful in the discovery process (Nyumba *et al.*, 2018). That was indeed the medium applied by several studies aiming to explore the impact of innovative technologies on the farmers under study (Carberry *et al.*, 2004; Dimes *et al.*, 2003; Falconnier *et al.*, 2017; Ronner *et al.*, 2019). On the other hand, Sempore *et al.* (2015) adopted an individual approach (working with each farmer separately) to investigate the strengths and weaknesses of three types of simulation models to assist crop-livestock farmers in Burkina Faso. Likewise, Andrieu & Nogueira (2010) implemented an individual approach in interacting with farmers and so designing a simulation model to support Brazilian farmers in evaluating the long-term effects of various farming managements. Different aims brought different strategies. In such a perspective, adopting a 'one-by-one' approach in the present project would not have been ideal. In fact, the stimulation of group dynamics in the context of the learning exercises, the case studies and the discussion groups, were intentions of the projects. Moreover, thanks to the workshop medium, it was possible to gather a number of 105 farmers; that would have been hardly achievable in such a limited amount of time via an individual approach.

Was the questionnaire the best way to record the farmers' feedback?

Other methods, such as individual interviews, could have been carried out to gather the farmers' feedback. That was indeed the approach applied by Carberry *et al.* (2004) and Sempore *et al.* (2015). In these studies the assessment of the modelling tool's impact, on the targeted farmers, was exclusively qualitative. This 'modus operandi' seemed to be particularly suitable in contexts with limited available quantitative data in which co-learning objectives were undertaken (Bennett *et al.*, 2013). Interviews are believed to provide a deeper understanding of social phenomena than would be obtained from quantitative methods, such as questionnaires (Gill *et al.*, 2008). In the present study, farmers' feedback were collected through questionnaires, learning exercises and notes taken during the discussion sessions. Given the relatively large number of people involved in the project and the limited amount of time, it was not reasonable to collect information person by person. Moreover, questionnaires happen to be cost-effective, time-efficient and allow to collect a greater (compared to individual interviews) quantity of data over a range of issues (Liamputtong, 2019). Although the participatory methodologies applied in the present study permitted to gather several qualitative insights, some 'interesting cases' could have blend in. It was indeed underscored the more market-oriented mindset of the bigger farmers and their greater interest in exploring investment opportunities via ex-ante analysis, compared to the smaller farmers. In such a perspective, the best medium could have been a combination of the two methodologies, implementing interviews both with farmers that showed a more or less market-oriented attitude. That, with the intention of supplementing the questionnaires feedbacks and thus obtaining a deeper understanding on the research objectives (Langat *et al.*, 2011).

The importance of the examples in the learning process

Guiding the non-modelling expert into this discipline, from the very basic to its application during a one day 'crash-course', was not easy. Different delivery/teaching methods were shaped to create an effective learning environment. The learning framework designed, followed the five principles of teaching identified by Merrill (2002): learners are engaged in solving real-world problems, existing knowledge is activated as a foundation for new knowledge, new knowledge is demonstrated to the learner, new knowledge is applied by the learner and so it is integrated into the learner's knowledge heritage. Because of the strong relation between the learner's existing knowledge and the new concepts, involving learners in relevant, interesting, and engaging real-world tasks is crucial (Jonassen, 1999). Moreover, there should be a progression from less to more complex tasks, in order to create an effective understanding on the topic discussed (Khalil & Elkhider, 2016). That was indeed the vision behind the workshop framing. The workshop was not focussed on the Dynmod model only, but on how agricultural modelling can assist farming decisions. Dynmod happened to be a relatively easy model case to introduce people to agricultural modelling and its benefits, but it was not the only example used. In such a perspective, while presenting conceptual modelling, not only the goat system but also the maize cropping system was described. Maize is one of the most common crops grown in Zimbabwe to sustain the household food security. Once harvested, it is processed into sadza (a type of cornmeal porridge), the staple meal for most of the locals. The sadza value chain, from maize sowing to the final product, was described in the form of a conceptual model. The potential connection between the goat and the maize systems was also exposed, where goats manure was used as a fertilizer while the maize stalk and/or straw was fed to the animals (**Appendix 11a**). Farmers were very responsive to the sadza example, even more than to the goat system. That is probably due to the fact that sadza is deeply rooted in their culture and traditions. In that viewpoint, the use of cases that enabled the emphatic engagement of the learners seemed the best option to deliver and communicate knowledge in the learning process.

At this point, the farmers' perception of modelling was that models could aid the system understanding. The next step was to let them be aware that models are also tools to investigate solutions to practical problems, hence assisting decision making. In order to guide farmers to this level of understanding, the weather forecast model was described. The weather forecast is the most common model in the non-modelling expert daily life; hence it was an effective way to show in a pragmatic manner how a model works. The large majority of the workshops' participants was aware of the weather forecast tool and consulted it mostly via the smartphone, in order to schedule and plan the agricultural activities (ploughing, sowing, etc.). Thus, it was assumed that a hypothetical farmer, wondering about the meteorological conditions of the next day, consulted the weather forecast in order to decide to till the soil or not. Therefore, it was shown how the weather forecast model simulates the weather of the next day giving a prediction. Based on that, the farmer was able to plan his farming practise (**Appendix 11b**). It was discussed the fact that the weather forecast, and so models in general, was not always producing accurate and reliable predictions. It was explained that a model is in fact a simplification of the real system; a simplification in which often not all the processes and not all the feedback dynamics are fully understood and represented. It was pointed out that models are not 'the voice of truth', the predictions' inaccuracy (more or less large according to the complexity of the model itself) is an intrinsic property of being a simplification of real systems. Farmers strongly agreed on this point. They stated indeed that sometimes, the weather predictions were wrong or inaccurate but still powerful means in exploring the uncertainties of the future and so assisting decision making. Most of the workshops' participants seemed to grasp the weather forecast analogy, which helped them to understand how agricultural modelling could aid farming decision making.

Both the maize cropping and the weather forecast models were effective learning pathways to guide the workshops' participants in the modelling topic. Examples made statements clearer, gave farmers more information, and decreased the chances that the ideas were misunderstood. Referring to concrete daily-life cases, rather than abstract concepts/contexts, led to develop relevant, legitimate and credible learning paths (Clark *et al.*, 2011). That method was also applied in the context of the participatory simulation stage, during which the simulations were tailored on real farming scenarios.

Some logistics issues faced

The workshop setting played an important role in the interaction with farmers. As mentioned, five workshops out of seven were conducted indoors while the remaining two in the open spaces. It turned out that many farmers were side-tracked by the open spaces distractions. Another relevant issue encountered in that context, was the wind disturbance affecting the flipcharts and so the information flow. The venue for a focus group is an important aspect and should preferably be accessible, private, quiet and free from interferences (Bloor *et al.*, 2001). Thus, an open space setting is highly unadvisable.

The seven workshops gathered a number of 105 people out of the 140 expected. Why was the demand for participants not satisfied? The farmers' selection and recruitment were assigned to the local extension officers, who were informed about the project's needs in advance on the beginning of the workshops. Once questioned on the possibility to meet the workshop's requirement, all the extension officers answered positively. Thus, the lack of participants could be imputed to the extension officers' inability in reaching the targeted farmers and/or to the non-responsiveness of the farmers who have been reached. The extension officers' service, crucial in the workshops setting, not always met the conditions agreed. That is probably not only due to reasons of 'force majeure' (e.g. networking and mobilization issues typical of the rural areas) but eventually also due to the low effort put in the task assigned. That's the case for the Takaliyawa workshop, during which most of the farmers complained indeed that they were informed too late on the workshop time and place. Two of them reported: *"Please notify us about these workshops in time so that we prepare"* and *"The work can be improved by spreading the information on time and date of the workshop so that every farmer can be able to attend the workshop on time"*. Not meeting the expected number of participants affected the amount of feedbacks gathered and thus the significance of the insights produced. It goes without saying that the larger is the sample size, the best the answers truly reflect the population (Fox *et al.*, 2007).

Sometimes problems were encountered in other logistical aspects of the workshop organization, such as finding a venue and recruiting the cooks. Another important issue faced, to a greater or lesser extent but recurring in all the workshops, was the delay in the commencement of the activities. As communicated to the extension officers, the beginning of the workshop event was scheduled at 08:30 in the morning. However, the big majority of the farmers were not punctual. In the best of the cases the workshop began at 11:00, while in the worst at 14:00. If people were keeping to the schedule there would have been more time for further insights and additional participatory simulations. However, despite these complications, all the workshops were successfully completed.

The workshops' participants

As mentioned, in the last years several research projects and NGOs' initiatives took place in the study area. Interviews, trainings and focus groups were conducted. Moreover, the seven villages in which the workshops have been organized were recommended by MRI's experts, who had ongoing projects there. Thus, the pro-active farmers' behaviour encountered in the workshops and the strongly positive feedbacks gathered on the workshops' evaluation, may partly be explained by the fact that Gwanda's people are used to take part in development projects. In such a perspective, dealing with people without any previous workshop experience, could have been more challenging and therefore the outcomes could have been different. This prompts the question, how representative were the workshops' participants for the smallholder farmers of semi-arid Zimbabwe?

It goes without saying that probably, the high degree of appreciation of the workshop framework could have something to do with the farmers' previous experiences in other research projects. In fact, the formation of new understandings rely on the integration of the learner's prior experience with new experiences (Falk & Adelman, 2003). Moreover, not only prior experience but also the interest in the topic, people's enthusiasms and expectations result to be relevant in the cognitive process (Kelsen, 2016). When it comes to the response on Dynmod and modelling in general, the fact that almost all the attendees did not have prior knowledge on modelling, could be a predominant factor compared to the farmers' previous experience in other participatory activities. However, the farmers' prior experiences in other workshops context could have played in favour to a better understanding on modelling. In fact, people with a stronger knowledge/experience heritage, are used to place lower demands on their working memory information processing, resulting in improved attention and focus, and thus learning efficacy (Kalyuga, 2007).

The farmers' categorization

Farmer typology research has become an important tool for designing farming intervention programs and targeting key messages to specific farmer groups (Schwarz *et al.*, 2009). In order to account for heterogeneity in the farmers' responses to modelling and their farming activities and practices, four smallholder goat farmers' classes were distinguished. However, fewer farmers than the expected were reached. The F1 class, the "very small" goat owners category (from one to five goats kept), was the most under-represented group. As discussed, that could be imputed to the extension officers' inability in reaching the targeted farmers and/or to the non-responsiveness of the farmers who have been reached. Still, the marginalization of smaller goat owners and/or their lack of interest in attending the workshop could also have played a role in that under-representation. However, another reason might be the inadequacy of the farmers' categorization outlined. In fact, the categorization adopted, due to time restrictions, was not the outcome of a systematic classification approach but rather a rough adaptation of the farmers' classes designed by Dube *et al.* (2014) in the Gwanda context. Thus, it is possible that the classes outlined did not fit properly in the real smallholder farming heterogeneity in the study site. That could account for the F1 class under-representation. A more accurate farmers' classification would have been great to better investigate the research objectives; several studies reported systematic classification approaches in development projects (Dube *et al.*, 2014; Falconnier *et al.*, 2015; Falconnier *et al.*, 2017; Foguesatto *et al.*, 2019; Leonardo *et al.*, 2015). The F1 farmers under-representation certainly affected negatively the relevance of the insight produced concerning the smaller goat owners.

The 'overload' of positive feedbacks, objective or biased?

99% of the attendees said "Yes" to the question: "Would you like in the future, to have modelling advices before any goat farming change". Furthermore, they answered unanimously "Yes" to the question: "Do you think that agricultural models, such as Dynmod, could help you in your goat farming activities". Still, the evaluation of the workshop's practices resulted in a strong general consensus (see **Table 11**). By looking at these numbers, a strong, common, positive opinion on agricultural modelling seems to be evident. Other studies, such as Carberry *et al.* (2004), which shows many similarities with the present project (in terms of aims and methodologies), also reported a strong positive consensus by the smallholder farmers and a general pro-active behaviour encountered in the workshop discussions. That is probably due to the participatory methodologies applied. However, such a "strong, common, positive opinion on agricultural modelling" has to be taken with a 'grain of salt'. In fact, it could be that such one-sided answers were determined by the farmers' need to be aided. In other words: smallholder farmers in this study's context experience high poverty conditions, and thus consider any and all help to be welcomed. Moreover, the overload of positive feedbacks could also be explained by the theory of planned behaviour (TPB) (Ajzen, 1991). TPB argues that how a person behaves, depends not only on the person's attitude but also on the subjective norms (such as the social context). In such a perspective, the perceived social pressure to perform or not to perform the behaviour, is constructed upon the beliefs about the perceived expectations of others to carry out the behaviour and the motivation to comply with these expectations (Meijer *et al.*, 2015). In other terms, it could be that farmers behaved according to how they supposed they were expected to behave (such as being thankful and compliant). Yet, farmers engaged in participatory research, change their consolidated social roles in households and communities (Hauser *et al.*, 2016). In fact, personal, family, and community preconditions could influence their ability and attitudes towards participatory research. As Hauser *et al.* (2016) reported: *"We found that the relation to extension workers influenced the level of engagement of farmers in participatory projects. The middle-class appearance of extension* *workers raised farmers' expectations to receive direct financial support. Consequently, some farmers feared jealousy from other community members leading to potentially dangerous situations such as the loss of reputation, exclusion from the community and the destruction of their fields and homes at the hands of jealous neighbours".* Still, the authors reported the potential effect of cultural beliefs (such as witchcraft) on the farmers' engagement in participatory projects. In that viewpoint, the influence of intrinsic and extrinsic factors could have played an important role on the participants' attitude and on the questionnaires' responses gathered in the seven workshops organized.

4.2 Farmers' perception on goat farming and modelling

Goat herd size and market orientation

The two main constraints affecting smallholder goat farming systems in semi-arid-Zimbabwe are high mortality rate and a too weak goat market. These limitations were firstly identified in the literature review stage and then confirmed in the context of the workshops organized. On top of everything, the weak goat market seemed to be the main limiting factor for improved goat farming. It is not a surprise indeed that fragile and uncertain market opportunities do not stimulate investments (Hockett & Richardson, 2018). That seems to be in line with Franke *et al.* (2014), who reported the tendency of the smaller farmers to be risk averse and therefore not keen to invest time and money (often scarse) towards more market oriented farming practices. Nearly 40% of the farmers gathered in the workshops, did not sell any goat in the last six months; most of them belonged to the F1 and F2 classes. However, it was noticed that generally the larger the goat herd size the more the farmer was market-oriented and the better he/she managed the herd, reducing its mortality rate (**Figure 6**). It might be inferred that the 'big' farmers tended to take goat farming as a profitable business rather than only a household subsistence activity (Ronner *et al.*, 2018). Compared to the owners of smaller herds, they showed greater intentions to invest money and time in improving the farming system and thus increasing their incomes (Wichern *et al.*, 2017). Still, the adoption rate of farming technologies happened to be often positively related to the farmer's resource endowment (Sietz & van Dijk, 2015). In fact, 94% of the farmers who reported to use commercial feeds, belong to the F3 and F4 classes (**Table 7**). Therefore, the goat market development should be the first important step in further developing the smallholder goat industry in Zimbabwe (Dube *et al.*, 2014).

'Draw your own goat farming system' exercise

Although the predominant western way of producing knowledge is based on scientific analysis, empirical observation and critical reflection, knowledge can be generated in different ways (Conquergood, 2002). Singhal & Rattine-Flaherty (2006) recognized the value of visuals, such as sketching and drawings, as alternative means of expression. That evolves in alternative ways of knowing to "textocentrism" (Williams, 1958), intended as "the privileging of text, writing and the lettered word as a mode of comprehension and expression" (Singhal & Rattine-Flaherty, 2006). In line with that, a number of 28 drawings were produced all over the workshops to stimulate the farmers' understanding on conceptual modelling. The outcomes showed that farmers grasped the conceptual modelling practice. Besides the strong appreciation of the practice reported in the questionnaires, it was possible to sense the farmers' engagement and enthusiasm in carrying out the exercise. From the other hand, the large majority of the information obtained in the present study resulted from "scientific analysis, empirical observation and critical reflection". In fact, as Hurston (1990) described, the textocentrism's issue is not the valorisation of literacy, but rather the valorisation of literacy to the exclusion of other forms of expression.

Participatory simulations

One of the most critical steps in the learning process was definitively the introduction of the mathematical aspect of modelling and so the role of the computer. It was explained that the role of computers in modelling is meant to solve several mathematic relations and so perform numerical calculations. At this point many farmers appeared a bit confused and seemed not to grasp completely the role of computer in modelling. Keeping in mind that 94% of the workshops' participants had never used a computer, that response was reasonable. However, once the participatory simulations were carried out, most of them 'got back on track', showing interest in the simulation practice. The farmers positive attitude towards that practise was in line with the observations reported by Carberry *et al.* (2004). Yet, the farmers interest in the participatory simulation was described by Martin *et al.* (2004), who reported: *"The participatory simulation provided many new elements for agricultural diagnosis and helped us improve the proposed crop–livestock model. Farmers were clearly interested in the proposed innovations and asked very relevant questions"*. Yet, the authors, during further follow-up visits in the study site, were able to notice a better awareness of the farmers on crop–livestock systems. Moreover, they were ready to undertake concrete actions toward issues met during the modelling simulations. Naivinit *et al.* (2009) reported the experience of a participatory modelling workshop with rice growers in a Thai village, with the intention of co-design an Agent-Based Model. The Companion Modelling (ComMod) approach (Bousquet & Trébuil, 2005) was undertaken for such a purpose. ComMod is an iterative, continuous and evolving approach to facilitate dialogue, shared learning and collective decision making through interdisciplinary and research in action processes (from several aspects similar to the DEED cycle exposed in chapter 1.4). Naivinit *et al.* (2009) reported: *"It was possible to use collaborative modelling with marginal rice farmers. We both researchers and participating farmers gained benefits through knowledge sharing by co-constructing the model"*. The workshops' participants interest and enthusiasm in carrying out the Dynmod participatory simulation sessions, seems to be in line with the other participatory modelling experiences just described.

Communication of modelling results

Agricultural modelling efforts have usually been oriented on the mathematics of the model, rather than keeping into account how to communicate modelling outputs to the stakeholders. The inclination of modellers and developers is to construct over-engineered systems (Holzworth *et al.*, 2018). Simulation models are often criticised for their lack of interactivity, not only in the application of decisions but also in the display of results (Moeseneder *et al.,* 2015). That probably contributed to the fact that simulation modelling has struggled in being relevant in real-world agriculture, having a tangible influence on farmers' decision-making (Carberry *et al.*, 2004). However, some project were more focused on improving the model interface, thereby trying to create models that are more user-friendly and accessible even for non-modelling 'insiders' (Muetzelfeldt & Massheder, 2003). According to Fischhoff (2013), science communication must perform several interrelated tasks: identify the relevant information for the people, determine what people already know, design communication to fill the critical gaps of knowledge and evaluate the adequacy of the way of communicating. Thus, identify the right mean of communication, communicate the right content and choosing the right 'language', stands out as crucial steps in science communication and so in modelling science. In the present project, these aspects were considered and undertook in designing the workshop learning framework and were explored in the modelling results communication issue.

Feng *et al.* (2019) developped a web interface for the application of the Agricultural Policy Environmental eXtender (APEX) model (Williams *et al.*, 2012) at the field scale in the US. APEX can help provide on-site information on pollution management related policies and serve as a communication tool among scientists, engineers, and stakeholders (such as farmers and ecologists). However most decision makers, might not have the knowledge to use the standalone APEX model. The new web interface was a medium intended to enhance interactivity, and so the usability of the modelling tool

(Moeseneder *et al.,* 2015). In line with that, but in a very different context, Beza *et al.* (2018) explored the applicability of using mobile SMS technology to share farming information with smallholder farmers in Ethiopia. In contrast to developed countries, where more advanced means of communication are available, to reach smallholder farmers in developing countries simple technologies such as mobile SMS are needed (Beza *et al.*, 2018). Mobile phones were largely utilized in the rural areas of Gwanda, thus applying mobile SMS technology to share modelling advices with smallholder farmers in the study site could be an effective mean of communication. Steinke *et al.* (2019) took a step further in using mobile SMS technology to share farming information with smallholder farmers (Ethiopia, Kenya and Tanzania). As a response to the vast heterogeneity of farmers' characteristics and so diverse information needs, the authors explored the feasibility of an automated advisory service able to collect household data from farmers and uses this data to prioritize agricultural advisory messages. The analysis shows that relatively limited data inputs from farmers, can be used to feed learning algorithms that continuously improve the targeting of specific advices. In fact, disseminating generic information to farmers with heterogeneous needs and interests may affect the relevance and trustworthiness of advisory messages, eventually leading to poor impacts on farmers' decision-making (Aker *et al.*, 2016). It could be infered that the studies above mentioned (Beza *et al.,* 2018; Feng *et al.,* 2019; Steinke *et al.,* 2019) were more focused on researching the right mean of communication and communicating the right content rather than investigating in the 'language' used to communicate that information. That aspect was indeed explored in the present study. In line with that, Sereenonchai *&* Arunrat (2018) conducted community-based participatory approaches to evaluate agricultural communication for climate mitigation with local rice farmers (in Thailand). Three main concepts were integrated and employed: science communication, integrated knowledge translation, and participatory communication. The authors, reflecting on the right medium to disseminate of knowledge, information, techniques and guidelines, underscored the importance of adapting the way of communicating science depending on the local context of each community. Yet, reporting: *"Illustrations should complement the written message by making it easier to understand and giving vivid examples of how to employ the farming technique that should be interesting and eye-catching, making the content more detailed and inviting. Any written message should be concise and easily understandable".* The present study investigated on this issue, exploring how the workshops' participants reacted to the different ways of presenting a model results proposed by Tullis (1981). It was found that the older the farmer and the lower his/her level of education the more he/she was prone to appreciate a model's result representation via images rather than column/line charts. These findings could be useful in further projects aiming to find the right language of communication in conveying models outputs to smallholder farmers. It goes without saying that further insights are needed in exploring such a crucial step.

5. Conclusions and recommendations

The aim of this project was to share modelling knowledge with smallholder farmers in the semi-arid southern Zimbabwe context. That, in order to increase the farmers' awareness on agricultural models and thus obtain feedbacks on how to improve our way of designing agricultural models and communicating models' results to the stakeholders. In order to achieve that, the framework of a participatory modelling workshop was designed and therefore applied in seven villages in the Gwanda district. Goat farmers were chosen as the target group, thus the goat farming model Dynmod was introduced to the workshops' attendees. However, Dynmod was not the focal point of this research, nor was its calibration, potential application or improvement. Rather, the focus was on the discussions that rose as a consequence of the simulation process. In such a perspective, Dynmod happened to be a relatively easy model case that allowed people to be introduced to agricultural modelling and its benefits. The application of the PLAR key concepts, allowed to obtain both quantitative (from questionnaires) and qualitative (from discussions and learning exercises) insights in the research objectives' investigation.

Smallholder farming practices were explored. It turned out that, even if livestock activities were the main source of revenue, crop production was performed by 90% of the workshops' attendees. The typical way of doing agriculture was indeed the mixed crop–livestock system. When it comes to small-scale livestock farming, goats happened to be one of the most kept livestock species in the study site. However, several limitations were present: high animal mortality, lack of institutional information on good farming practises and a too weak goat market. The findings of this thesis underscored that the bigger the goat herd the lower is the animal mortality rate throughout the different age/sex classes. Moreover, a more market-oriented attitude was found for the 'bigger' farmers. In fact, compared to smaller goat owners, they were inclined to put a stronger effort in improving their farming practices (animal nutrition, housing and management). Nevertheless, the issue of the weak goat market was often addressed in the discussions both from smaller and bigger goat owners. Therefore, the goat market development should be the first important step in further developing the smallholder goat industry in Zimbabwe.

When it comes to the farmers' perception on modelling, the learning exercise 'draw your own goat farming system', produced a total of 28 drawings all over the workshops. Most of the representations were box-and-arrow diagrams, describing the main goat farming sub-systems and the relationships between these entities, showing the farmers' understanding on the conceptual modelling practice. Participatory modelling simulations, based on real farming input-data communicated by the farmers, were run and collectively analysed. 99% of the farmers reported that participatory simulations were useful for their understanding on modelling. Attention was given to the communication of modelling results issue. It was found that, the older the farmer and the lower his/her level of education the better he/she preferred a model's result representation via images. The opposite trend was found for the graphic representations (line and column chart). These findings could be useful in further projects aiming to find the right language of communication in conveying modelling outputs to smallholder farmers. Overall, farmers unanimously considered agricultural models as helpful tools to explore farming activities.

The findings of this thesis captured the workshops' participants interest in receiving modelling-based advices, to explore farming decision making. The strong farmers' positive response to Dynmod and modelling in general, can lay the basis for further projects in which smallholder farmers will be assisted in their practices through simulation modelling. This, in turn, can enhance livestock productivity in semi-arid Zimbabwe and thus support the small-scale livestock keeper.

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7. Appendix

Appendix 1*: Uses of goats as reported by goat keepers in Katerere, Nyanga North district in Zimbabwe (Mhlanga et al. 2018).*

Use	Frequency (%)
Meat	96.2
Manure	96.2
Selling	92.5
Wealth	87.5
Skins	70.0
Cultural purposes	46.2
Ceremonies	27.5
Prestige	20.0
[3]*Kupira*	20.0
[1]*Kuchenura*	16.2
[2]*Bira*	15.0
[5]*Lobola*	13.8
[4]*Kurasira*	12.5
Milk	9.5

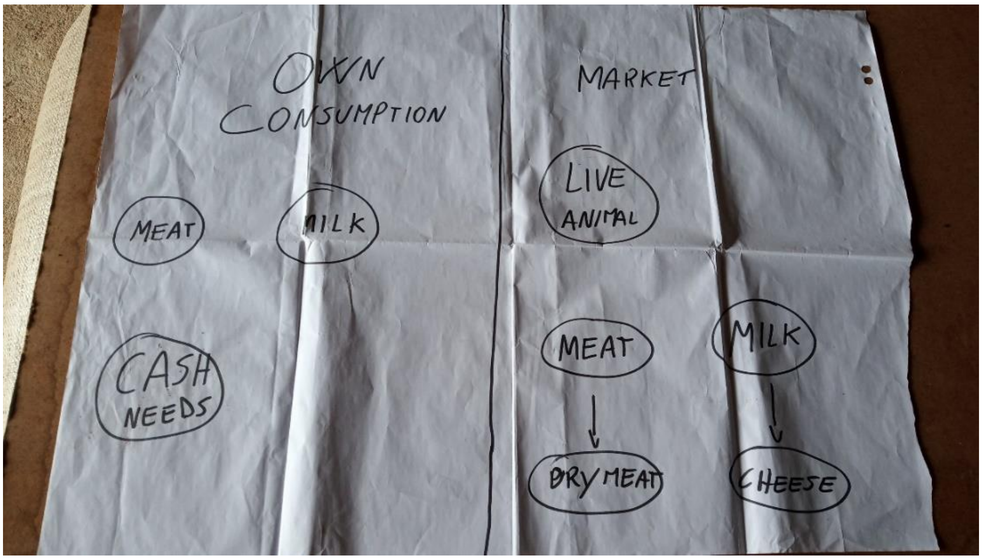
Vernacular terms for; [1]*Memorial service;* [2]*Brewing of beer in remembrance of the deceased;* [3]*Dedication of spirit mediums on bucks;* [4]*Exorcism of evil spirits;* [5]*Bride price.*

Appendix 2: *Gwanda farmers categories. Source: Dube et al. (2014).*

	C1	Very resource poor farms: These farms cultivate the smallest area and have the smallest herd sizes. Household heads are relatively old, least educated and family sizes are small. They have least contact with extension and the least diverse sources of information. The proportion of female-headed households is high. They have lowest incomes and face greater food shortages.
	C2	Poor but stepping up farms: Households have limited cropland and livestock, but highest proportion of off-farm activities. Household heads are slightly younger. Their annual household income is three fold that of the resource poor households.
	C3	Intensifying cattle maize farms: These farmers are mainly located in Gwanda North, with higher rainfall and cultivate more than double the land than the other types. Herd sizes are intermediate. Household heads are older. Female-headed households are few. Their income levels are low.
	C4	Intensifying crop-livestock farms: These farms are the wealthiest, owning more than four times the number of livestock as compared to the resource poor farms. They also have the highest number of contacts with extension. Female-headed households are few. In contrast to C3 with large croplands, these farms with large herds earn the highest annual incomes.

Appendix 3: *Some of the handmade flipchart slides.*

Appendix 4: *The stone game flipchart.*



__Appendix 5:__ "How to show a model result" framework.

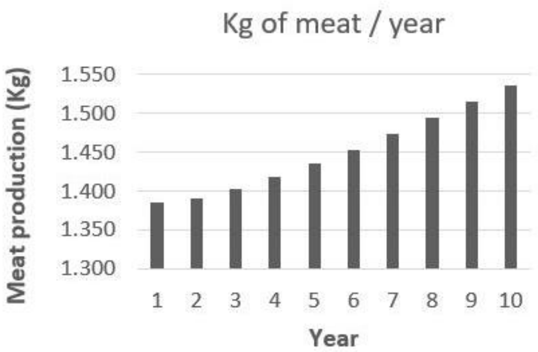
- *Narrative*

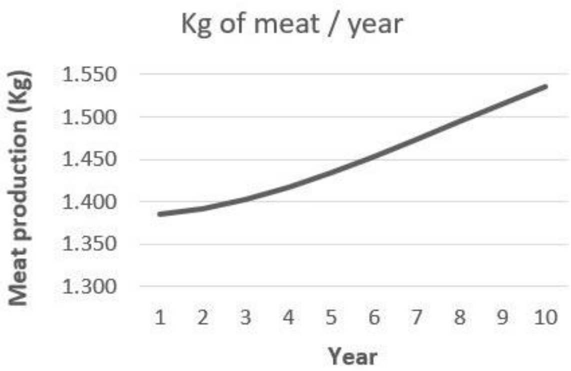
  "The model simulation reported an increasing goat meat production by 10% in 10 years. Thus, growing a new forage crop is worthwhile for your business"

- *Table*

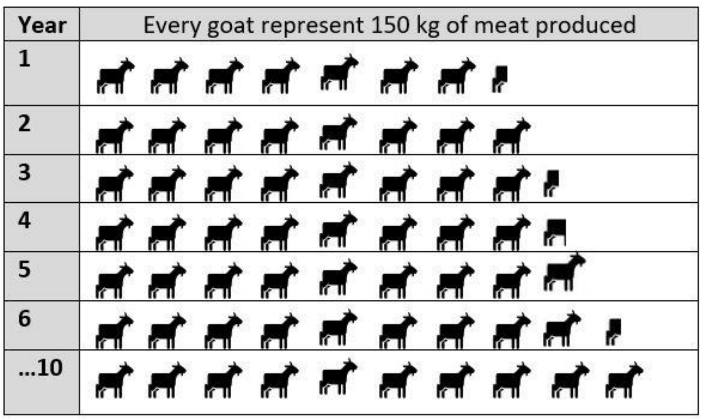
Year	1	2	3	4	5	6	7	8	9	10
Meat production (Kg per year)	1,385	1,391	1,402	1,417	1,435	1,545	1,473	1,494	1,515	1,536

- *Column chart and line chart*

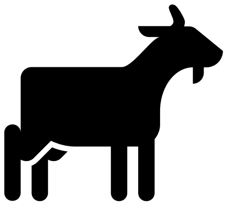




- *Images*



Appendix 6: *Full-text questionnaire.*



QUESTIONNAIRE

Imibuzo yokuthola yolwazi

In goat we trust

Silethemba embuzini

Country ____________________________

Province ____________________________

District ____________________________

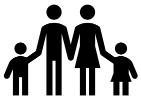
Ward ____________________________

Village ____________________________

Date: ____________________________

1. General Information

1. Imniningwane ejwayelekileyo



Who are you?

Ungubani?

1.1 Name: ________________________________
1.1 Ibizo

1.2 Surname: ________________________________
1.2 Isibongo

1.3 What is your relationship to the household head? (tick the option)
1.3 Ulobudlelwano bani lophethe umuzi? (Khetha kumpendulo ezilandelayo)

Household head *Nhloko yomuzi*		Wife of head *Nkosikazi*		Brother *Mfowabo*		Sister *Dadewabo*	
Son *Ndodana*		Daughter *Ndodakazi*		Other (specify)______________ *Loba lapha (nxa bungaqanjwanga ubuhlobo)*			

1.4 How old are you? ___________________
1.4 Uleminyaka emingaki

1.5 Number of people resident in the household (enter the number)
1.5 Inani labantu abahlala lapha ekhaya (bonisa ngokugcwalisa kumizila elandelayo)

Age class (years) *Izinga leminyaka*	Males *Abesilisa*	Females *Abesifazana*
< 6		
6-15		
15-40		
40-70		
>70		

1.6 What is your level of education? (tick the option)
1.6 Izinga lemfundo yakho? (Tshengisa kumabhokisi alandelayo)

☐ Elementary school — *Izinga Lokucathula*
☐ Primary school — *lakuqala (e primary)*
☐ High school — *Izinga lesibili (e secondary)*
☐ University — *evasithi*

1.7 Have you ever used a computer? (tick the option) Yes ☐ No ☐

1.7 Sewake wasebenzisa " i-computer" ?(Tshengisa kubhokisi)
If Yes, how often? (tick the option)
Nxa impendulo yakho phezulu ingu "yebo(yes)", tshengisa ukuthi uyisebenzisa ngemva kwesikhathi esinganani ngokukhetha kumpendulo ezilandelayo:

☐	☐	☐	☐
Every Day	Weekly	Monthly	Once a year
Mihla yonke	*Kanye ngeviki*	*Kanye ngenyanga*	*Kanye ngomnyaka*

For which purpose? (tick the option/s)
Khetha ibhokisi/amabhokisi atshengisa injongo yokusebenzisa "i-computer"

☐	☐	☐	☐
Social network	Agricultural information	Meteo information	Other(specify): _______________
Ukuxhumana Lomphakathi jikelele	*Ezabalimi*	*Isimo somkhathi*	*Ungaqamba okunye ngokuloba*

1.8 Where do you get most of your income? (tick the option/s)
1.8 Yiziphi indlela othola ngazo inzuzo/imali? Khetha kumbe uqambe ezinye kwezilandedlayo:

a. Crops *Izilimo*		b. Livestock and products *Izifuyo*		c. Home industries *imisebenzi yezandla*	
d. Salary *Iholo*		e. Other (specify): ________ *(okunye)*		f. Other (specify):______ *(oKunye)*	

(rank up to 3: ***1*** - ***2*** - ***3***. *1 is the higher source of income, 3 is the lower*)
Qathanisa ngesisindo imithapho yemali ehlukeneyo othola ngayo imali/inzuzo kusukela kumthapho 1 oyiwo oletha inzuzo engcono kusiya ku 3 umthapho wenzuzo ephansi kuyo yonke

---

2. Farm Assets

2. Impahla yomlimi

What do you own?

Kuyini olakho?

2.1 Land holding (enter the number of hectares)
2.1 Umhlabathi (umkhulu kangakanani)

a. Crop area (ha) *a. Amasimu/Insimu*		b. Grazing area (non-communal) (ha) *b. Amadlelo*	

2.2 Which crops did you grow in the last five years? (tick the option/s)

2.2 Yiziphi izilimo obuzilima okweminyaka emihlanu edlulileyo?

Maize *Umumbu*	Sorghum *Amabele*	Legumes *Indumba*	Forage crops *Ukudla kwezifuyo*	Other (specify) ________________________ *okunye*

2.3 How many animals of each species do you actually own? (enter the number of animals)
2.3 Kuhlobo lwezifuyo ezilandelayo, ulezingaki?

Species *Uhlobo lwesifuyo*	Cattle *Inkomo*	Sheep *Izimvu*	Goats *Imbuzi*	Donkeys *Obabhemi*	Pigs *Ingulube*	Chickens *Inkukhu*	Other (specify): ___________ *Ezinye*
Number of animals *Inani lezifuyo*							

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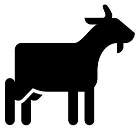
3. Goat farming and Management

3. Ukufuya lokunakekela imbuzi



3.1 How many goats do you have at the moment? (enter numbers by sex and age class)
3.1 Zingaki imbuzi okwakathesi?

Age class *Ubudala*	***Male*** *Ezinduna*	***Female*** *Ezinsikazi*
Juvenile (0-3 months) *Amazinyane*		
Sub-adults (3-12 months) *Amaguqa*		
Adults (more than 12 months) *Ezindala*		

3.2 How many kids were born in the last six months? (enter numbers)
3.2 Kuzelwe amazinyane amangaki kunyanga eziyisithupha ezedluleyo? Faka amanani kumabhokisi alandelayo:

Male *Ezinduna*	***Female*** *Ezinsikazi*	**Total**

3.3 How many goats died in the last six months? (enter numbers)
3.3 Kufe imbuzi ezingaki kunyanga eziyisithupha ezedluleyo? Faka amanani kumabhokisi alandelayo

Age class *Ubudala*	***Male*** *ezinduna*	***Female*** *ezinsikazi*
Juvenile (0-3 months) *Amazinyane*		
Sub-adults (3-12 months) *Amaguqa*		
Adults (more than 12 months) *ezindala*		

3.4 What are the major causes of mortalities in your herd?
3.4 yini mbangela yokufa kwazo evamileyo ?

Diseases *Imikhuhlane*		Starvation/malnutrition *Ukuswela ukudla okweneleyo*	
Predation *Ukudliwa zinyamazana*		Water availability *Ukuswela amanzi*	
Other: (specify)_______________ *(Okunye)*		Other: (specify)________________ *okunye*	

(rank up to 3: ***1*** - ***2*** - ***3***. *1 is the higher cause of mortality, 3 is the lower*)
Phana izisindo kumbangela yokufa kwazo , u-1 esiba yimbangela enkulu kusehlela ku-3 encinyane yakhona

3.5 How do you manage your goats during the day? (tick the options)
3.5 Uzigcina njani imbuzi emini? Khetha kumbe wengeze kumpendulo ezilandelayo

Herded *ziyeluswa*		Tethered *Ziyabotshela*	
Paddocked *Zivalelwa emadlelweni*		Free range *Ziyazibonela*	
Other: (specify)_________ *Okunye*			

3.6 Which type of goat housing, for the night, do you own? (tick the option)
3.6 Zilala kusibaya esinjani? Khetha kumpendulo ezilandelayo

I do not own a goat housing *Kazila sibaya*		Open kraal *Esingafulelwanga*	
Brick walls and roof *Esezitina lophahla*		Wooden kraal with roof *Esezigodo esilophahla*	
Other: (specify) _________ *Loba nxa singaqanjwanga*			

3.7 Do the goats have enough grazing? *Yes* ☐ *No* ☐
3.7 Amadlelo azo ayenela na?

3.8 If no, what are the supplementary feed utilized for goats? (tick the options)

3.8 Nxa impendulo yakho phezulu isisthi, hatshi(No),ziphiwani okokwengeza njengokudla?

cereal straws *amakhasi entanga*		Legumes *Ukudla okucebileyo/indumba*	
Forages *Izillimo zokudla kwezifuyo*		cereal grains *intanga*	
garden garbage *okusuka kuzivande/engadini*		commercial feeds ***ukudla okuthengwayo***	
other (specify)____________________ *(okunye)*		other (specify)____________________ *(okunye)*	

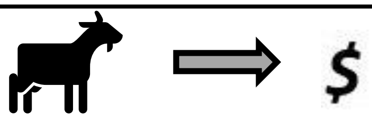
3.9 Do you fertilize your fields with the goat's manure?

3.9 uyasebenzisa na umquba wembuzi emasimini?

Yes ☐ *No* ☐

4. Goat Offtakes

4. Ukuphuma kwembuzi



4.1 How many goats were <u>sold</u> and <u>bought</u> in the last six months? (enter numbers of animals)

4.1 Zingaki imbuzi ezithengisiweyo kanye lezithengiweyo kunyanga eziyisithupha ezedluleyoyo(gcwalisa kuzikhala ezilandayo)

	<u>SOLD</u> *Ezithengisiweyo*		***<u>BOUGHT</u>*** *Ezithengiweyo*	
Age class *Ubudala*	***Male*** *Ezinduna*	***Female*** *Ezinsikazi*	***Male*** *Ezinduna*	***Female*** *Ezinsikazi*
Juvenile (0-3 months) *Amazinyane*				
Sub-adults (3-12 months) *Amaguqa*				
Adults (more than 12 months) ***Ezinkulu***				

4.2 What are the major problems that you are facing in goat farming? (rank)

4.2 Zinhlupho bani ezinkulu ohlangana lazo ekufuyeni imbuzi?

(rank up to 3: ***1*** - ***2*** - ***3***. *1 is the bigger problem, 3 is the smaller*)

Phana isisindo kusukela kwenkulu isiba ngu-1 kusiya k-3 encinyane yakhona

1= feed and water availability *Ukudla lamanzi*		2= marketing of goats *Umkambo wembuzi*	
3= diseases *imikhuhlane*		4= theft *Ukwebiwa kwazo*	
5= predators *Ukubanjwa egangeni*		6= availability of veterinary services *Ukuswelakala kwabe veterinari*	
7= other (specify)____ (Okunye)			

4.3 What is the current market price (in US $) for the following categories?

4.3 Gcwalisa okulandelayo ngemininingwane yentengo

	Live animal *(US $ / Kg)* *Eziphilayo*		**Goat Meat** (US $ / Kg) *Inyama*		**Goat Milk** (US $ / Litre) *Uchago*
Age class *Debele*	***Male*** *Ezinduna*	***Female*** *Ezinsikazi*	***Male*** *Ezinduna*	***Female*** *Ezinsikazi*	***Female*** *Ezinsikazi*
Juvenile (0-3 months) *Amazinyane*					//
Sub-adults (3-12 months) *Amaguqa*					//
Adults (more than 12 months) *Ezindala*					

4.4 Do you slaughter your own goats before selling? *Yes* ☐ *No* ☐

4.4 uyahlaba/uyabulala imbuzi ungakayithengisi?

4.5 Do you process the goat meat before selling? *Yes* ☐ *No* ☐

4.5 Uyalungisa inyama ungakayithengisi na?

4.6 Do you consume goat milk? *Yes* ☐ *No* ☐

4.6 liyadla inyama yembuzi?

4.7 Do you sell goat milk? *Yes* ☐ *No* ☐

4.7 uyathengisa uchago lwembuzi na?

4.8 Do you process goat milk (for example into cheese)? *Yes* ☐ *No* ☐

4.8 uyalungisa uchago lwembuzi uluguqulele kwezinye izinto?

4.9 Are you part of a goat farmers association? *Yes* ☐ *No* ☐

4.9 uyingxenye yenhlanganiso egxile kwezembuzi na?

---

5. Modelling

5. indlela yokwenza

5.1 Did you know something about agricultural modelling before the workshop? *Yes* ☐ *No* ☐

5.1 ubulolwazi na malungana lendlela yokulima/ukufuya ungakezi kulombuthano?

5.2 Do you understand the importance of agricultural modelling in helping farmers? *Yes* ☐ *No* ☐

5.2 uyazwisisa yini ukuqakatheka kwezokulima ekusizeni abalimi?

5.3 Do you think that agricultural models, such as Dynmod, could help you in your goat farming activities? Yes ☐ No ☐

5.3 ucabanga ukuthi indlela yokulima/ukufuya enjenge- Dymod, ingasiza na ekufuyeni Imbuzi?

5.4 Would you like in the future, to have modelling advices before any goat farming change? Yes ☐ No ☐

5.4 ungathakazelela yini ukucetshiswa njalo ngendlela zokufuya imbuzi ungakaguquli oyisebenzisayo?

5.5 What are in your opinion the main advantages of goat modelling? (tick the option/s)

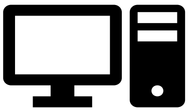
5.5 Ngokuzwisisa kwakho,incomeka kanjani indlela ye (goat modelling)?

Predict herd performance *Iyaveza ngaphambilini inguquko*		Simulate catastrophic event (drought) *Iyavikela indlala*	
Calculate the income *Iyatshenisa inzuzo*		Explore investment opportunities *Iyatholisa amathuba okwenza inzuzo*	
Other: (specify)____________________ *(okunye)*		Other: (specify)____________________ *(okunye)*	

5.6 Would you like to study computer modelling, in order to use models by yourself? Yes ☐ No ☐

5.6 ungathakazelela ukuqeqetsha ku-(computer modelling)ukuze wenelise ukuzenzela?

6. Dynmod model



6. Indlela ye Dynmod

6.1 What are, the more useful Dynmod's outputs for your goat farming? (tick the option/s)

6.1 Yiphi impumela enhle ngeDynmod ekufuyeni kwakho imbuzi?

Live animal production *Ukugxila kuzifuyo esiphilayo*		Meat Production *Ukugxila kwezenyameni*	
Milk Production *Ukugxila kwezochago*		Skin Production *Ukugxila kwezezikhumba*	
Financial Equivalent *Inzuzo kwezemali*		Investment options and risks Analysis *Imobono yamabhizimusi lokucubungulisa ingozi*	
Other (specify)____________________ *(okunye)*		Other (specify)____________________ *(okunye)*	

7. How to present a model result

7. Indlela yokuveza impumela

<u>*Example:*</u>

Mr. Jabulani is a goat farmer in Gwanda district. Yesterday he went in a Research Institute office with a really specific question: "I want to grow a new forage crop in my backyard in order to feed my Matebele goats. Is it a good idea or just a loss of money?". The researchers, based on the Jabulani's herd numbers, ran a simulation on the computer and gave back to him an answer on his investment idea.

Umnumzana Jabulani ongumfuyi wembuzi eGwanda uvakatshele indawo yabaqeqetshi abahlaziya ngezokufuya. Umnumzana Jabulani ubelombuzo ocacileyo kakhulu, kanti wona obunje: " ngifisa uku lima isilimo esiyikudla embuzini zami ezibizwa ngokuthi (Matebele goats). Lokkhu ngifisa ukukwenzela ngemva kweguma lami ngekhaya. Ngabe lombono uqondile yini kumbe kungaba yikulahlekelwa yimali nje?" Ngokukhangela inani lembuzi zikamnumzana Jabulani,Ingcwethi zisebenzise umtshina I "computer" ukucubungula lelicebo emuva kwalokho basebemupha impendolo eqondane lombono wakhe.

The researchers' results, from Dynmod model, are proposed in 4 different ways:
Impumela yomqeqeshi kusetshenziswa indlela ye- "Dynmod "ingaba ngendlela ezine:

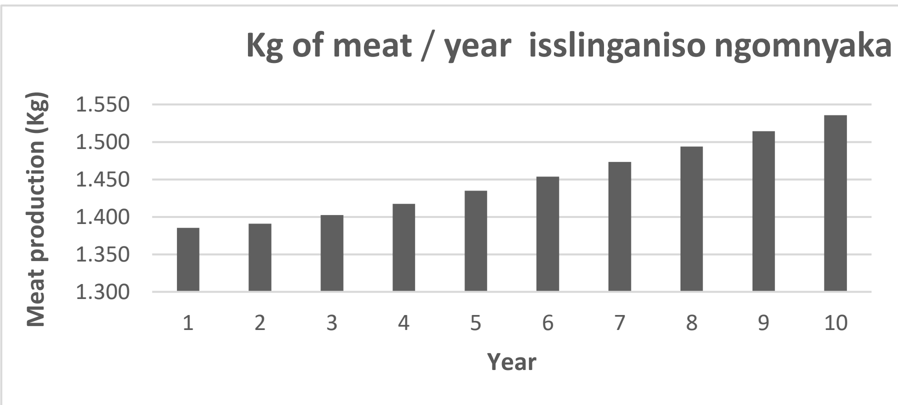
1. Narrative:
1. Ngokulandisa

The model simulation reported an increasing goat meat production by 10% in 10 years. Thus, growing a new forage crop is worthwhile for your business.
Indlela yokucubungula iveze ukuthi kuzakuba lokwanda kwenyama yembuzi ngetshumi ekhulwini(10%) eminyakeni elitshumi ezayo. Ngakho ukulima lesisilimo kungaba yinzuzo

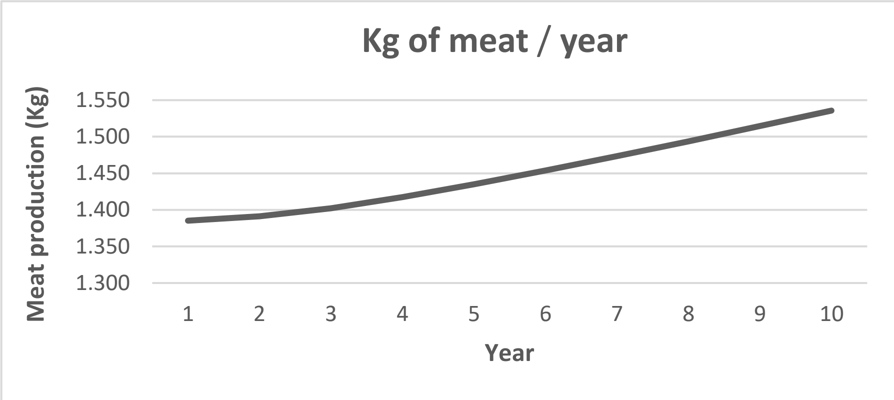
2. Table:
2. Ngokudweba

Year *Umnyaka*	1	2	3	4	5	6	7	8	9	10
Meat production *Ibhizimusi lenyama* ***(Kg per year)***	1,385	1,391	1,402	1,417	1,435	1,545	1,473	1,494	1,515	1,536

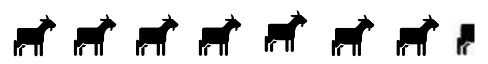
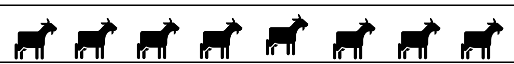
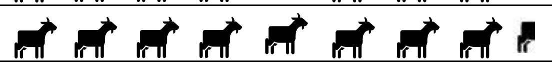
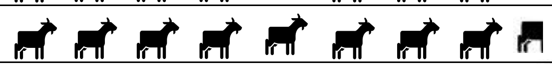
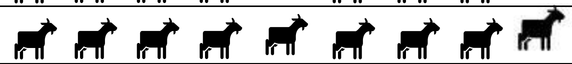
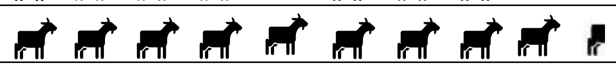
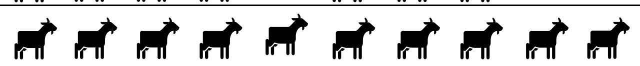
3.a Chart Column:
3.a ukudweba



3.b Chart Line:
3.b ukudweba



4. Images:
4. Imifanekiso

Year	***Every goat represents 150 kg of meat produced*** *Imbuzi ngayinye imele amakilogram alikhulu lamatshumi amahlanu enyama*
1	
2	
3	
4	
5	
6	
…10	

7.1 Which one was clearer to you? (rank)
7.1 yiphi indlela ekucaceleyo ukwedlua ezinye?

1. Narrative:	2. Table:	3.a Chart Column:	3.b Chart Line:	4. Images:

(rank up to 5: ***1*** – ***2*** – ***3 – 4 – 5*** . *1 is the clearest, 5 is the less clear*)
Tshengisa ngokupha isisindo kusukela ku-1 yona elesisindo esikhulu ukwedlula zonke kusehla kusiya ku -5 yona elesisindo esiphansi kulazo zonke.

8. The workshop

8.1 What is your overall opinion about the workshop “In Goat We Trust”? (tick the option)
8.1 ngombono wakho, ube unjani lombuthano/workshop we “ In goat we trust?”

I very enjoyed it *Ngikhwabithile kakhulu*		I enjoyed it *ngikhwabithile*	
I did not enjoy it a lot *Kangikhwabithanga kangako*		I did not like it at all *kangiyithandanga*	

8.2 Was the workshop duration too long? Yes ☐ No ☐
8.2 Ngabe le workshop ibende kakhulu?

If Yes, what is the optimal duration that you recommend? (in hours) ____________________
Nxa uyibone inde kakhulu, cebisa ngesikhathi ongasikhangelela (ngamahola)

8.3 How much did you enjoy the talk/lesson from the facilitator (Jabulani)? (tick the option)
8.3 Ukholise kangakanani imfundiso yomqondisi (uJabulani)

I very much enjoyed it *Ngikholise kakhulu*		I enjoyed it *ngikholisile*	
I did not enjoy it a lot *Kangikholisanga kangako*		I did not like it at all *kangiyithandanga*	

8.4 Have the flipcharts learning support been useful to your understanding? Yes ☐ No ☐
8.4 Ngabe usizakele ngokusetshenziswa kwamaphepha abhaliweyo?

8.5 How much did you enjoy the exercises done (such as the “draw your conceptual model”)?
8.5 Ukhwabithe kangakanani izivivinyo oziphiweyo, ezinjengokudweba?

I very much enjoyed it *Ngikhwabithe kakhulu*		I enjoyed it *ngikhwabithile*	
I did not enjoy it a lot *Kangikhwabithanga kangako*		I did not like it at all *kangiyithandanga*	

8.6 How much did you enjoyed the participatory modelling session? (tick the option)
8.6 ukhwabithe kangakanani ukuphatheka ku modelling?

I very much enjoyed it *Ngikholise kahulu*		I enjoyed it *ngikholisile*	
I did not enjoy it a lot *Kangikholisanga kangako*		I did not like it at all *kangithakazelelanga*	

8.7 How much did you enjoy the division in sub-groups? (tick the option)
8.7 ukholise kangakanani ukuba semaqenjini?

I very enjoyed it *Ngikhwabithe kakhulu*		I enjoyed it *ngikhwabithile*	
I did not enjoy it a lot *Kangikhwabithanga kangako*		I did not like it at all *Kangithandanga lutho*	

8.8 Has the participatory modelling session been useful to your understanding of modelling?
8.8 ukuphatheka ku modelling ngabe kukusizile yini?

Yes ☐ No ☐

8.9 Would you like to attend again, in the future, a workshop like that?
8.9 Ungajabulela ukubuya njalo kumhlangano onjengalo?

Yes ☐ No ☐

8.10 Was the food and beverages supply good enough for you?
8.10 Ngabe ujabulele ukudla lokunathwayo na ?

Yes ☐ No ☐

8.11 Are you willing to explain what your learned today to other farmers not present to the workshop?
8.11 uyafisa na ukwabelana labanye abalimi abangenelisanga ukuza, ngemfundo oyitholileyo?

Yes ☐ No ☐

9. The Questionnaire

9.1 As you have seen this questionnaire was both in English and in Ndebele. How much did you enjoy the Ndebele translation? (tick the option)

9.1 Ujabulele kangakanani ukutolikwa kwesilungu siguqulelwa kulimi lwesiNdebele?

I enjoyed it very much *Ngijabule kahulu*		I enjoyed it *ngijabulile*	
I did not enjoy it a lot *Kangijabulanga kangako*		I did not like it at all *kangikuthandanga*	

9.2 Was the Ndebele translation useful for your understanding? *Yes* ☐ *No* ☐

9.2 Ngabe ukuguqulela kulimi lwesiNdebele kukusizile na?

9.3 Thanks to the Ndebele translation, did you manage to fill the questionnaire independently? *Yes* ☐ *No* ☐

9.3 Wenelisile ukuphendula imibuzo wedwa?

If no, how much of the questionnaire (on average) did you manage to fill independently? (tick the option)

Nxa uthole usizo,tshengisa ukuthi wenelise kangnanani ukuziphendulela eminye imibuzo

75%		50%	
25%		0%	

9.4 Please give us any recommendation/suggestion on how to improve our work for the next time!

9.4 Phana umbono wakho ngokuthi ukhangelele intuthuko ngaphi kumsebenzi wethu kwelizayo

____

____

____

____

Thank you very much for your availability!

Siyabonga kakhulu ubukhona bakho

The facilitator: Francesco Erminio Longhini

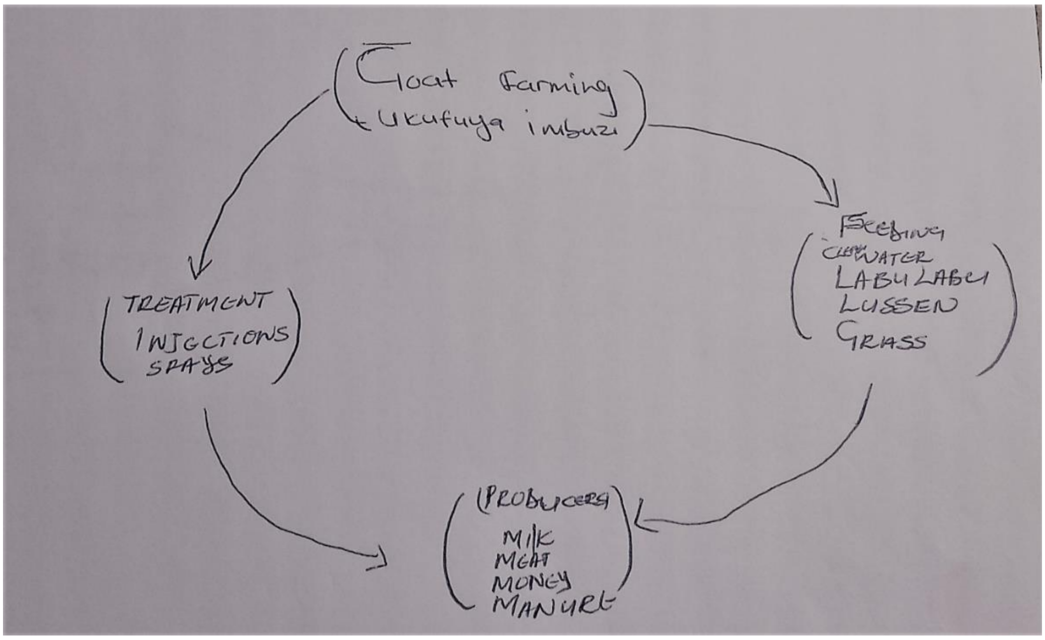
WAGENINGEN UNIVERSITY & RESEARCH

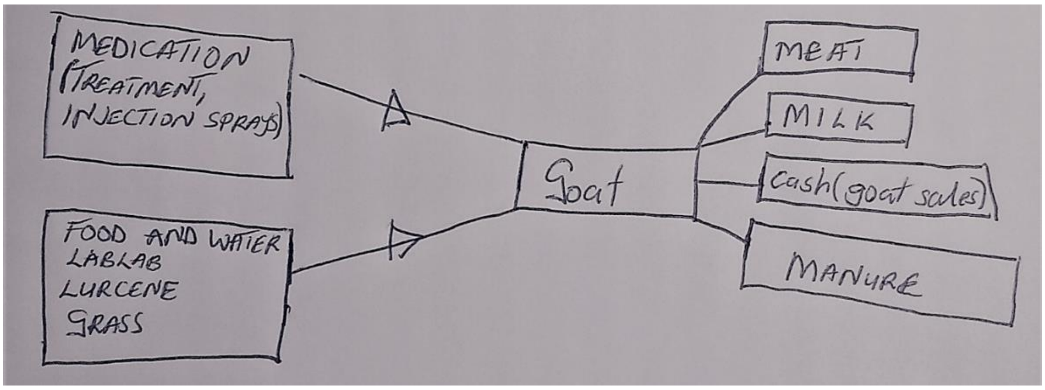
DEPARTMENT OF RESEARCH AND SPECIALIST SERVICES R&SS ZIMBABWE

Appendix 7: *Dynmod parameters.*

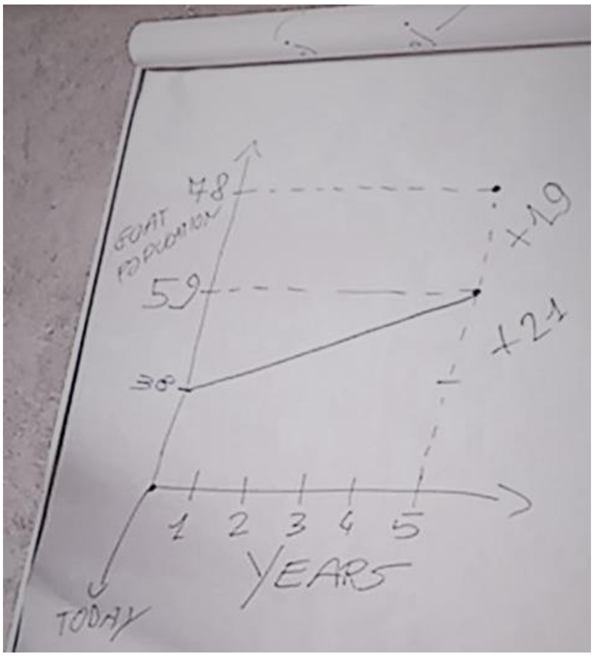
Parameter		***Value***	***Unit***	***Source***
Age classes	Female Juvenile	3	Months	Consultation of MRI experts, annual reports and local veterinary officers
	Female Sub-adult	12	Months	"
	Female Adult	105	Months	"
	Male Juvenile	3	Months	"
	Male Sub-Adult	12	Months	"
	Male Adult	45	Months	"
Reproduction rate	On rate	1	Birth / Year	Lesnoff & Julien (2014)
	Net prolificacy rate	1.5		Lesnoff & Julien (2014)
	% of female at birth	50%		Lesnoff & Julien (2014)
Mortality	Female Juvenile	50%		Consultation of MRI experts, annual reports and local veterinary officers
	Female Sub-adult	15%		"
	Female Adult	15%		"
	Male Juvenile	50%		"
	Male Sub-Adult	15%		"
	Male Adult	15%		"
Offtake	Female Juvenile	0%		"
	Female Sub-adult	0%		"
	Female Adult	15%		"
	Male Juvenile	0%		"
	Male Sub-Adult	0%		"
	Male Adult	15%		"
Live Weight	Female Juvenile	20	Kg/animal	"
	Female Sub-adult	30	Kg/animal	"
	Female Adult	40	Kg/animal	"
	Male Juvenile	20	Kg/animal	"
	Male Sub-Adult	35	Kg/animal	"
	Male Adult	50	Kg/animal	"
Carcass Yield		50%		"
Milk Production	Length of milk	100	days	"
	Milk offtake	0.15	Litre/day	"
Manure production	Juvenile	0	Kg/day	Lesnoff & Julien (2014)
	Sub-Adult	0.1	Kg/day	Lesnoff & Julien (2014)
	Adult	0.3	Kg/day	Lesnoff & Julien (2014)
Feed Intake		2.5%	% / Weight	Lesnoff & Julien (2014)

Appendix 8: "Draw your own goat farming system" *exercise output from the Nhwali and Gungwe workshops.*





Appendix 9: *Participatory modelling results analysis on the flipchart.*



Appendix 10: *Open-ended question feedbacks.*

Complaints	**Looking further**
The workshop was good, but I was not happy that there were not enough white papers to take down notes	As a farmer I realized the importance of the workshop. I therefore request your office to mobilize the water system improvement. Thank you.
The lesson was good, but we did not get the notepad	I am looking forward to implementing what I learnt.
Please notify us about these workshops in time so that we prepare	I am looking forward to learning a lot from workshop how to manage and look for markets
The work can be improved by spreading the information on time and date of the workshop so that every farmer can be able to attend the workshop on time	We need help with goat farming and more lessons
Time has to be limited to 3 hours	Please come again, we need more lessons and medication.
These workshops should begin earlier	Looking forward to learning more about goats
To come early and dismiss early	Please reach even to those who are not practicing goat farming so that they also see the importance of goat farming.
I would like to have a notepad. Please explain things slowly so that I can take everything down	I want to build a shelter for my goats and vaccinate my goats
This work should be spread over 2 days	May you come again tomorrow if possible, to help us more
	We would like to know about sheep modelling
	We would like to learn about chicken and cattle modelling
	Come back and teach us how to build roofs and grow fodder crops, thank you very much

Appendix 11: *The sadza production and the weather forecast conceptual models.*

Appendix 12: *Flipchart describing the logical step from conceptual to mathematical modelling.*