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USE OF SIMULATION TO ESTIMATE ECONOMIC PERFORMANCES OF TWO PHENOTYPES OF SOWS

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ABSTRACT

A simulation model representing the dynamics of a sow farm is presented in contrast with other modelling approaches. To highlight relevant aspects of the model a real application for comparing two different groups of sows is considered. The main contribution of the model is that it is flexible to represent different sow herd management alternatives through an extensive number of input parameters. This features allow to measure the productivity of sows under different set of parameters and performing virtual experimentation. The example presented here is related to estimate economic performances of two phenotypes of sows from a real experiment. Phenotypes consist of sows resistant to a common disease (porcine reproductive and respiratory syndrome) with respect another group sensitive to the same reproductive disease. Furthermore, the implementation in Extend performs efficiently additional calculations to enlarge the understanding of the productive behavior in each case.

1 INTRODUCTION

Different sow herd management models have been developed and introduced for on farm use (Plà 2007), but they have not been widely used (Kamp 1999; Gelb 1999). There are farm management areas where decision tools are less developed, especially when tactical and strategic decisions are involved (Rodriguez et al. 2014). This is a surprising fact, taking into account that strategic decisions are important for farm viability. Maybe the simplicity required in getting the big decisions right and making correctly the major tactical adjustments (Pannell et al. 2000) is the reason. However, the availability of tools to compare alternative management strategies is always needed and simulation models can play an important role on that.

Sow herd management is the process by which certain goals of a sow farm manager, are expressed as the relationship between the amount of product achieved consuming a corresponding amount of production factors or resources. It is usual to make system simplifications in order to get practical herd models although conserving the essence of the real system. The challenge of the livestock modeler is to represent what is essential in the system in order to find relevant answers from a problematic situation that may initially seem chaotic (Pla 2007). Once the simulation model is developed it can be used instead the physical system in simulation experiments. Simulation models are flexible with regard to initial state, time horizon, discount rate, management strategies and randomness and can represent real situations. Simulation of sow farms can be useful to study either the average outcome and its dispersion over time of different management policies or the economic and productive behavior of different phenotypes under the same herd management policy. In this work we focus in the latter. Thus, a simulation model of sow herd dynamics is introduced and an application related to the estimation of economic performances of two phenotypes under the same management policy from a real experiment is presented. One phenotype corresponds to sows resistant to a common disease, the porcine reproductive and respiratory syndrome (PRRS), with respect the other phenotype sensitive to the same reproductive disease.

2 THE SOW FARM OPERATION

2.1 Basics of Sow Herd Management

Traditional pig farming was held in one farm, the so called farrowing-to-finish farms. Nowadays, because of specialization and disease problems pig farms are organized in a pork supply chain involving multi-site multi-farm systems (Rodriguez et al. 2014; Nadal and Plà 2014). Then we can find sow farms producing piglets, rearing farms and fattening farms producing pigs as well as any combination of them. At the same time, pig production has been tending to concentrate in fewer firms. The essence of this modern and competitive organization relies on an efficient piglet production. Thus the piglet production system is characterized by a herd of sows in a continuous process of reproduction. The piglets are the commercial product, which after weaning are transferred or sold to rearing-fattening farms depending if they are owned or not to the same company. This specialization gives additional efficiency gains and it is widely extended within the Spanish swine industry.

Daily operations in a sow farm are weekly scheduled in commercial farms. This way work force is more efficient operating the farm. As result, sows are grouped in batches allowing an efficient rationalization of tasks. For instance, matings or inseminations are performed on Tuesday and Wednesday, weaning of piglets is done on Thursday and Friday and heat control and gestation detection on Monday. This weekly planning of activities is rarely took into account by livestock models and even they represent a lot of complexities for a structured mathematical modeling approach. In addition, the impact of changes in reproductive management or the comparison of management alternatives should consider this aspects of extreme practical importance.

2.2 The Porcine Reproductive and Respiratory Syndrome

The porcine reproductive and respiratory syndrome or PRRS, is one of the most important disease affecting pig production at present. The problem relies on the difficult diagnosis beforehand, the virulent affectation when declared, the lack of efficacy medicines to treat and the negative impact on farm productivity. In this context, veterinaries are looking for ways to cope with this disease and mitigate the negative effects. One way is the detection of animals showing resistance or immunity to the disease.

3 DEVELOPMENT OF THE SIMULATION MODEL

3.1 The Development Framework: ExtendSim

The simulation model was implemented in ExtendSim 9.2, an interactive general purpose simulation tool (Krahl 2013; Krahl and Nastasi 2014) with 2D and 3D animation capabilities. The ExtendSim simulation environment provides the tools for all level of modelers to create accurate, credible, and usable models in an efficient way as recommended by Law and Kelton (2000). The selection of a proper simulation software can make a significant difference in how well simulation analyses support managerial decision making. Thus, ExtendSim was chosen because it facilitated every phase of the simulation project, from creating, debugging, verifying, and validating the model, to the construction of a user interface.

An ExtendSim model is created by adding blocks to a model worksheet, connecting them together, and entering the simulation data. Each block has its own functionality, dialog, help, icon, and connections. Each instance of a block in the model contents its own data. An additional advantage is the ExtendSim's built-in, compiled language, ModL, to create reusable modelling blocks beyond the standard libraries provided by ExtendSim. All of this is done within a single, self-contained software program that does not require external interfaces, compilers, or code generators. Hierarchical blocks help to organize the model and this kind of blocks can be added to the model in number equal or greater to one being very useful to make the model more readable. For instance, each sow can be encapsulated as a sub model into a hierarchical block representing a crate. At the same time, a hierarchical block representing the farm can be built integrating different crates occupied by a sow.

3.2 Conceptual Model and Prototyping

A first prototype was implemented following the conceptual model shown in Figure 1. Conceptual model took the reproduction cycle as base. The implementation of the simulation model was incremental. First of all, the representation of the reproduction cycle of a sow was modelled and number of piglets were the outputs. Animation features of ExtendSim were used to perform proof of concept involving successive refinements and checking the rationale of the model. Farm representation was modelled as a set of sows put together in the same block. All blocks are responsive to blocks containing parameters representing the productive performance of the farm and many herd management settings like the duration of different reproductive states like gestation or lactation. These important parameters served also to define the herd management strategies like weaning at a fixed age of piglets or at the same time for a batch of sows regardless the age of piglets (minimum 21 days). This stage ends up once the preliminary version of the simulation model was conceptually accepted.

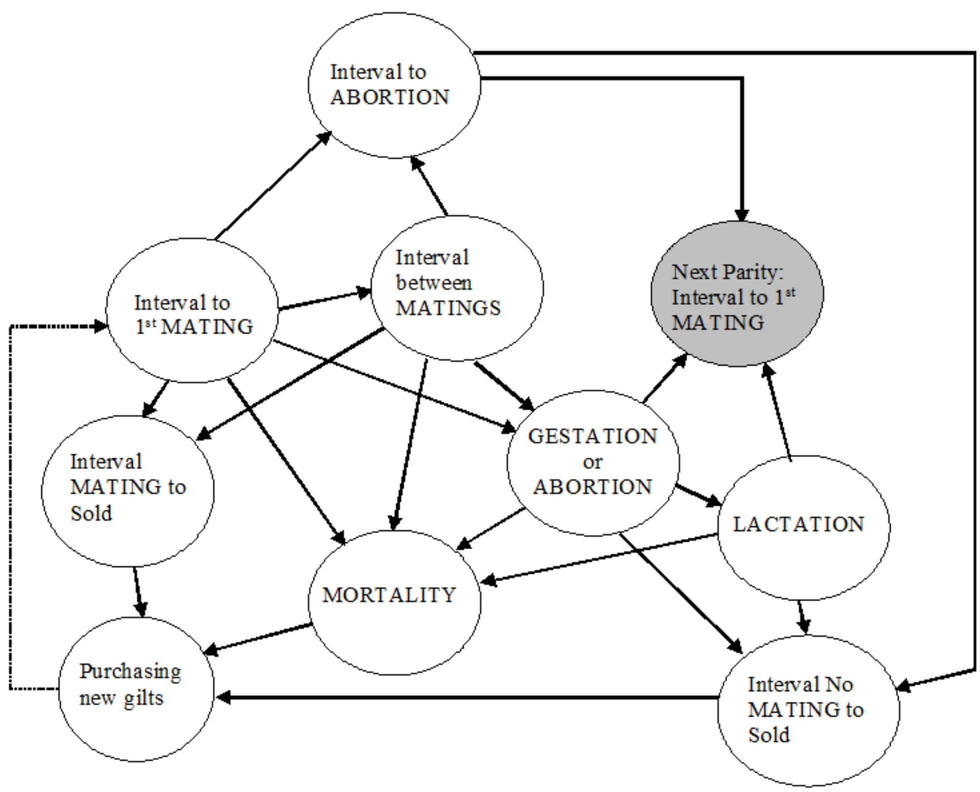

Figure 1: States and transitions of a sow cycle.

3.3 The Simulation Model

Model structure is presented in Figure 2. Main elements of the model are: the hierarchical block of general parameters, the hierarchical block representing the farm and the block registering piglets produced. All of them are tailored made blocks that can be complemented with standard ones as the Plotter I/O or the File Out blocks.

The blocks of general parameters and the farm are hierarchical blocks because they are built from other blocks. For instance, the block of parameters named "Parameters Sow Farm" contains four blocks each one representing a set of parameters affecting herd dynamics: abortion, conception, culling and technical issues as shown on the left of Figure 2. Each farm can be customized in terms of general and individual parameters ruling the production and reproduction process.

The hierarchical block of the farm contains blocks representing each individual sows or more properly, a crate, as it can be empty or occupied along the simulation. Each individual sow model operates according to the functionality represented in Figure 1. So that, the basic component of the farm simulation model is the crate where each animal that can be housed in. All these elements are hold in a user library and so, farm size is customizable adding more or less sows to the simulated farm.

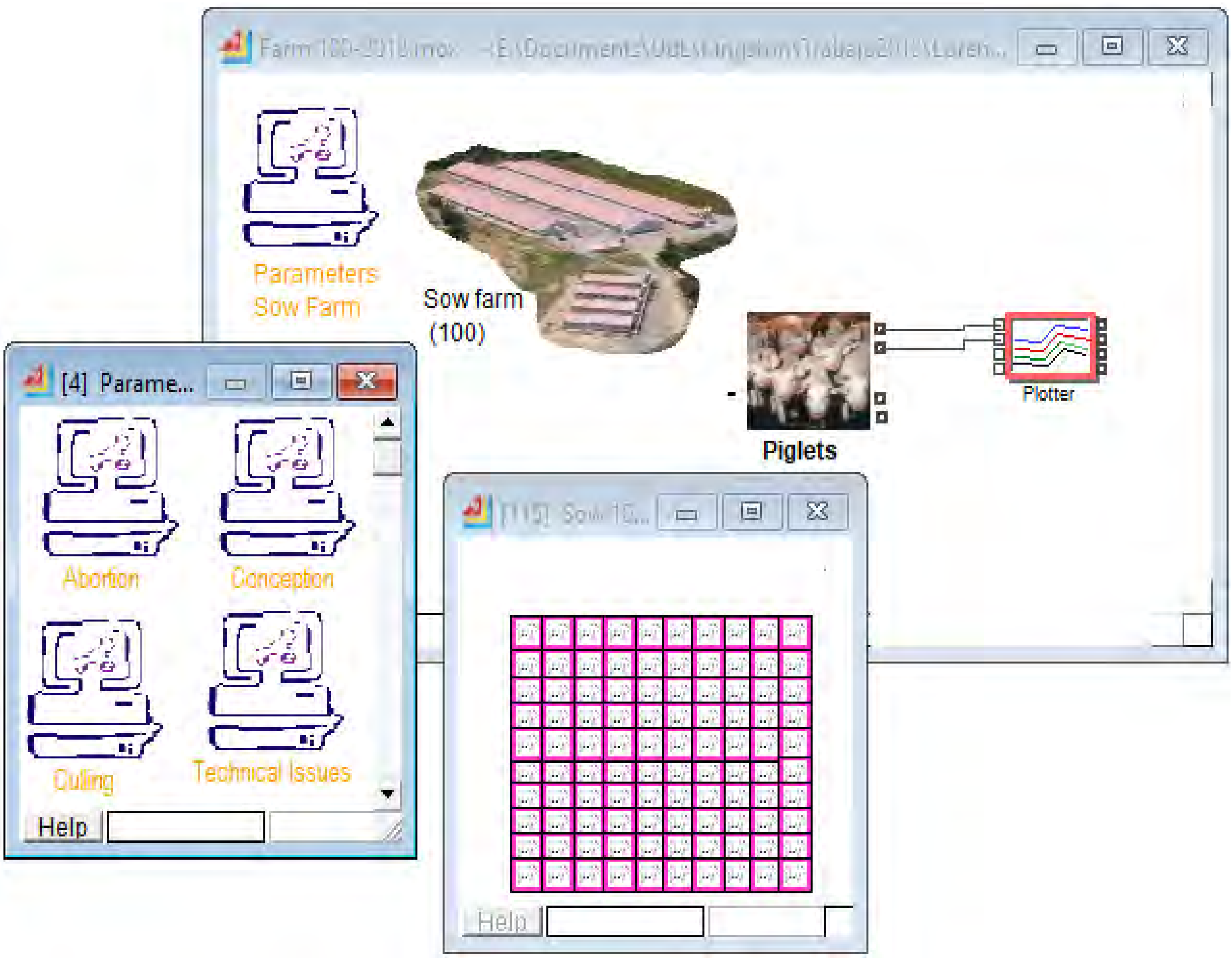

Figure 2: Model overview showing the hierarchical blocks of parameters (Block [4] including four groups of parameters: Abortion, Conception, Culling and Technical issues) and the block of sow farm (Block [115] including square crates in pink simulating a sow each) open.

In fact this model is a refinement of that presented in Plà (2005). Main differences are concerning the new set of parameters included to better represent a wide range of management alternatives and the management of data generated during simulation. For instance, these alternatives allow to consider batch management of sows, weekly operations on the farm, replacement rules like abortion or low litter size and the introduction of capacity constraints for lactation facilities. This way, the virtual representation of different real management strategies is flexible and capable to be more realistic and accurate. As result, comparisons between farm systems are better analyzed and more reliable.

3.4 The Simulation Experiment

There is a long term experiment that started with the findings of Abella et al. (2016) regarding the resistance analysis of several sows regarding the PRRS disease. In this context, two groups of sows (namely PCR0 and PCR1) are under the same management policy in a commercial farm suffering in the past PRSS outbreaks. The idea of the real experiment is to expose these two phenotypes (resistant and not) to a possible future outbreak and to analyze the immuno-response and the productive behavior. Sows of both phenotypes are living together in a commercial farm merged with other sows and receiving the same treatment. The farmer do not know which are these animals to avoid preferences among sows. Key production indexes are collected regularly and registered as for the rest of the sows in the farm and following the standards in Spanish commercial farms. In the meantime, it was proposed to investigate the productive behavior of the two phenotypes in view of finding discrepancies and detecting different behavior in absence of the disease outbreak.

As sows involved in the experiment were introduced in batches in the farm, merged with the rest of sows in the farm, it is difficult to assess differences in production between phenotypes. Hence, it was proposed to conduct a simulation experiment using the previous presented simulation model updated with all the value parameters and technical indexes observed for each of the two groups. As result, two virtual farms housing virtually one of the phenotypes will be built, simulated and analyzed to estimate productive and economic performances.

4 EXPERIMENTATION AND PRELIMINAR RESULTS

The number of sows available to extract value parameters for each phenotype were of 133 for PCR0 and 248 for PCR1. Most of the registered sows were still alive and productive on farm and only 23% of PCR0 and 21% of PCR1 have been already culled. The eldest sows are in the fifth reproductive cycle, but most of the active sows are in the fourth reproductive cycle. Parameters of performance beyond the fourth cycle are considered the same for the two groups. All differential parameters used in the simulation experiment are presented in Appendix A.

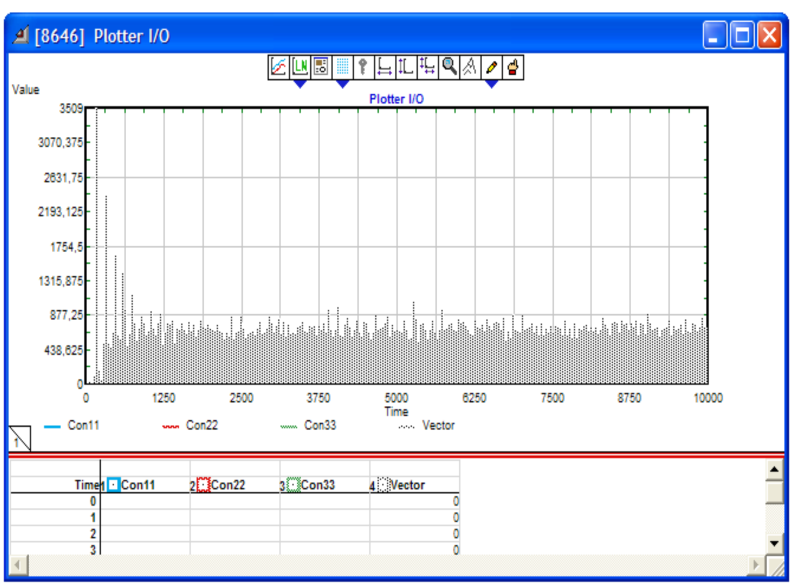

Figure 3: Piglet production over time.

For all simulation runs were considered twelve years (4380 days). A warming period of 6 years (2190 days) was considered before extracting statistics. Piglet production was considered the main output of the model directly related with economic output as many authors recognize (Plà, 2007). Hence, Figure 3 shows the plot of piglet production over time when variability was not considered. The main result obtained to compare both phenotypes was number of piglets weaned per weaning (shown in Table 1). A total of thirty runs were considered to make the comparison of a two sample t-test of means. Significance differences was found ($p<0.001$).

Table 1: Summary of piglet production from t=2190 to T=4380.

Phenotype	N	Mean weaned	StDev	Litter size
PCR0	30	10.075	0.005	11.30
PCR1	30	9.901	0.005	11.39

A detailed inspection of the simulation results was surprising as it is already seen on Table 1, sows of group PCR1 have a bigger litter size than PCR0. However, herd dynamics provokes that final result at weaning, sows of PCR0 show a better performance. In this sense, all technical parameters and key production indexes show better figures for sows of group PCR1 except for a slight difference in culling rates (Table 4) and piglets weaned (Table 5). These differences are the elements serving to explain the final outcome of the model.

The real experiment is not over on field, so it will be necessary to wait for the conclusion and collection of all the data to corroborate the results observed when comparing both prototypes. However, these preliminary results served to value the technical and economic impact of a sow phenotype resistant to the PRRS disease.

5 CONCLUSIONS

The simulation model described here represents a practical approach for representing the operation of a sow farm under different sets of parameters. The use of a visual simulation tool like ExtendSim is useful to interact with specialist and produce a flexible tool. The simulation model considered variations in sow performance and can explore the performance of two different phenotypes. We have illustrated the utility of the model comparing two phenotypes of sows resistant to the PRRS disease with respect another group not resistant to the same disease. The estimates of economic performances represented by average number of piglets weaned per sow per year in absence of a disease outbreak do show significant differences between genotypes. However, it would be required to repeat the analysis once the experiment be finished and all the data available.

A PARAMETERS OF THE SIMULATION MODEL

The parameters enumerated here are those calculated specifically for each phenotype and making the difference in the simulations. Then, virtually farms are simulated with the parameters showed by each phenotype.

That is, both phenotypes are under the same management policy and results are the expression of corresponding phenotype. Considered parameters are classified in random time intervals (Table 2) related with the nodes presented in Figure 1, time intervals under farmer's control (Table 3), transition probabilities (Table 4), litter size and piglets weaned per parity (Table 5) and management requirements for each virtual farm simulated (PCR0 and PCR1). Distribution of random time intervals shown in Table 2 are extracted from the exploratory analysis introduced in Marin et al. (2005) and distribution values of parameters updated with the experiment data.

Table 2: Random Time Intervals.

Time interval	Distribution in days	
	PCR0	PCR1
Interval to first mating	Γ(5.94,0.5)	Γ(5.60,0.5)
Interval between matings	N(22.62,3)	N(21.36,3)
Gestation	N(116,2)	N(116,2)
Abortion	*weib*(5,60)	*weib*(5,75)
Interval mating to culling	N(28,3)	N(28,3)
Interval otherwise to culling	N(7,3)	N(7,3)

As mentioned, in this experiment, the decisions regarding reproductive management strategies are considered the same for both virtual farms representing the same environment rules provided by the farmer. For instance: size of batches of sows or the delay between batches, the maximum lifespan (fixed at 9 reproductive cycles), the maximum number of mating per reproductive cycle (two matings maximum), the number of abortions permitted (only two abortions per sow). Lactation management involves decision variables affecting weanings like when piglets are weaned (scheduled every week), the minimum age of piglets for being weaned (three weeks of lactation). The farm size was set to 600 sows and the warming period for the farm of 6 years with a time horizon of 12 years.

Table 3: Time Intervals under farmer's control.

Time interval	Distribution in days	
	PCR0	PCR1
Lactation	23.27	23.33
Time interval to be moved to gestation facility after mating	28	28
Time interval to be moved to lactation facility before farrowing	7	7
Drying period after weaning	7	7

Parameters related to parameters under farmer's control are the same for both prototypes. The lactation period is slightly different between phenotypes as weaning is not performed at a fixed aged. Transition probabilities in Table 4 represent the probability of going from node to node depicted in Figure 1.

Table 4: Transition Probabilities.

	Probability	
	PCR0	PCR1
Conception1	0.8267	0.8534
Conception2	0.7586	0.6840
Conception3	0.6477	0.5212
Conception4	0.6825	0.7805
Conception+	0.7000	0.7000
Abortion	0.0533	0.0468
Mortality	0.007	0.012
Casualties	0.013	0.012

Table 5: Litter size.

	Litter size		Weaned	
	PCR0	PCR1	PCR0	PCR1
Parity 1	10.51	10.67	8.83	8.83
Parity 2	11.12	11.73	9.83	9.26
Parity 3	11.87	11.28	10.65	10.00
Parity 4	11.56	12.62	10.49	10.54
Parity 5+	11.57	11.33	10.49	10.40

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