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Investment Decision based on a Genetic Algorithm to Optimize the Profitability of Fattening-sheep Farming

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Abstract—**In this work, the investment decision making was based on the Genetic Algorithm (GA) results about optimizing the profitability of fattening-sheep farming in the state of Veracruz, México. Initially, a simulation of a fattening-sheep semi-extensive farming system was performed, supported in statistic records and experiences of sheep farmers, so the appropriate system features and factors involved allowed the simulation model to represent the real system complexity. As most of these factors have an inherent uncertain behavior, this was considered through probability distributions. The economic analysis included the initial investment, cash flows and Net Present Value (NPV), which were estimated using the Monte Carlo simulation results for a chosen alternative. Finally, a GA was used to maximize the NPV and to support the decision about the best alternative regarding factors such as initial number of ewes, type of breed, type of sale, and planning horizon. These ones were considered key factors because they determine the rest of the variables behavior, e.g. initial number of rams, land area required, mortality rate, proliferation, prices in market, to name just a few. In conclusion, simulating the fattening-sheep farming system considering the system uncertainty in the economic analysis and maximizing the NPV with a GA, allowed the investment decision making for this project to be based in all possible scenarios analysis, identifying the scenario with the best profitability.**

Index Terms—**Economic analysis, genetic algorithm, investment decision making, Monte Carlo simulation**

I. Introduction

México is a country with gastronomic richness, and meat is an important ingredient in its cuisine. About 84% of Mexican households are fond of some type of meat[†] [1], but meat demand cannot be supplied by the production of the country, having to import mainly chicken meat, pig meat, and sheep meat [2]. The main livestock producing states in México are Jalisco and Veracruz, in which sheep production is below cattle, chicken, and pig production [3], [4]. Taking this premise as starting-point we know that México needs investment projects to increase meat production, especially of sheep, and Veracruz plays an important role for this purpose due to its agro-ecological features and productive potential. Economic evaluation studies done about sheep farming in México have established the profitability of this activity [5], [6], but this research is trying a different approach: to optimize the profitability by means of a Genetic Algorithm (GA).

Genetic algorithms [7] are used as a sophisticated tool of optimization, which is based on the principles of Darwin's theory of evolution by natural selection, and nowadays have been used to approach problems in the agricultural sector, mainly in disease control areas; however, its application can be extended to business, simulation, and identification areas [8].

This work begins representing the fattening-sheep semi-extensive farming process, from the initial acquisition of the animals to their commercialization, using a model of simulation which supplies information for a second stage of the analysis, in which income statements for a period under consideration are presented and the Net Present Value (NPV) is estimated. In a third stage of this study, a GA is run to optimize the NPV and to support the investment decision making regarding the setting of variables analyzed.

This analysis proposal allows studying influential factors such as: proliferation, loss of life, animal weight, and market price, to name just a few. The factors have been represented in the simulation model through probability distributions, and the annual initial and final stocks were previously estimated with Monte Carlo simulation. The aim of optimizing the project profitability is according to four key variables: initial number of ewes, type of breed, planning horizon, and type of sale.

II. Methodology

The economic evaluation studies are based on normative criteria, independent of subjective opinions, which indicate preferences in any course of action. Every alternative is independent of the other ones and the measure of the economic preferences is made separately. Renkema and

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[†] Fish and seafood consumption is excluded for this estimate.

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Berghout [9] distinguish four basic approaches to evaluate investment alternatives: the financial approach, the multi-criteria approach, the ratio approach, and the portfolio approach. Methods from the financial approach are usually recommended for the evaluation and selection of investment alternatives. Often used financial approach methods are: the Payback Period (PP) method, the Internal Rate of Return (IRR) method, and the NPV method. The latter is used to evaluate this project.

The NPV method compares the alternatives using an *n* years period of time, which not necessarily considers the total duration of the alternatives. This period is called planning horizon. The NPV function is defined as

$$NPV = -P + \sum_{1}^{n} \frac{CF}{(1+MARR)^{n}} + \frac{SV}{(1+MARR)^{n}}, \qquad (1)$$

where *P* is the principal (present sum), *CF* is the cash flow, *MARR* is the minimum acceptable rate of return, *SV* is the salvage value, and *n* is the planning horizon (number of periods in which the project is expected to exists).

As the aim of this research is to maximize the profitability of fattening-sheep farming, the objective function is established as

$$Max\ NPV = -P + \sum_{1}^{n} \frac{CF}{(1+MARR)^{n}} + \frac{SV}{(1+MARR)^{n}}. \qquad (2)$$

Before putting the GA into practice to solve the function, the initial investment and cash flows must be estimated. This was carried out as shown in Fig. 1.

The data included in the cash flow were estimated using a Monte Carlo simulation, considering initial investment and uncertain parameters related to the animals such as: mortality rate, production (birth rate), animal replacements, among others. These were represented according to established probability distributions to deal with decision making under risk. The data used to perform the simulation were obtained from México's Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food (SAGARPA stands in Spanish) [10].

The approach of simulation applied for the economic evaluation is summarized in the following stages [11]:

--*Stage 1: To create alternatives.* For this research, the alternatives studied depended on the combination of six types of sheep breed (Dorper, Damara, Pelibuey, Katahdín, Blackbelly, and Suffolk), an initial number of ewes (between 100 and 300), the planning horizon (between 2 and 10 years), and two types of sale ("on-the-hoof" and carcass).

--*Stage 2: To identify parameters with variation.* The parameters which present variation were identified. These are listed in Table I.

--*Stage 3: To determine the probability distributions.* Depending on the type of variables, discrete or continuous, the corresponding best fit probability distribution was chosen, as indicated in Table I. In this stage, the selection of the probability distribution was based on information from different sources. The available information in government databases was not enough to apply goodness-to-fit tests; however, the information used was supported by manuals for farming education [12].

--*Stage 4: To run a pseudo-random sampling.* The procedure to generate pseudo-random samples for the Monte Carlo Simulation was performed. The results obtained until this step fed the economic evaluation database, which included the initial investment, operating expenses and costs of goods sold with the planning horizon chosen, obtaining this way the NPV for the alternative considered. The next step was the application of the GA.

TABLE I
PARAMETERS WHICH HAVE UNCERTAINTY IN THE FATTENING-SHEEP FARMING AND THE DISTRIBUTIONS THAT BETTER REPRESENTED THEM

Parameters	Units	Probability Distribution Used
Animals to leave mortality	Percentage	Normal probability distribution
Average weight of animals when leaving	Kilograms	Normal probability distribution
Average weight of replaced ewes "on-the-hoof"	Kilograms	Normal probability distribution
Average weight of replaced rams "on-the-hoof"	Kilograms	Normal probability distribution
Costs of maintenance supplies of machinery	Mexican pesos	Triangular probability distribution
Costs of maintenance supplies of the vehicle	Mexican pesos	Triangular probability distribution
Ewes "on-the-hoof" unit price to sell	Mexican pesos	Triangular probability distribution
Ewes in carcass unit price to sell	Mexican pesos	Triangular probability distribution
Ewes mortality	Percentage	Normal probability distribution
Ewes unit price to buy	Mexican pesos	Normal probability distribution
Lambing	Percentage	Normal probability distribution
Lambs "on-the-hoof" unit price to sell	Mexican pesos	Triangular probability distribution
Lambs in carcass unit price to sell	Mexican pesos	Triangular probability distribution
Number of lambs by every lambing	Heads	Normal probability distribution
Petrol	Litres	Triangular probability distribution
Pre-weaning lambs mortality	Percentage	Normal probability distribution
Rams "on-the-hoof" unit price to sell	Mexican pesos	Triangular probability distribution
Rams in carcass unit price to sell	Mexican pesos	Triangular probability distribution
Rams mortality	Percentage	Normal probability distribution
Rams unit price to buy	Mexican pesos	Normal probability distribution
Weaning animals mortality before to leave	Percentage	Normal probability distribution

A GA allows an initial population composed of individuals with particular features, to evolve under setting rules to get the best result of the objective function [13]. The GA structure [14] is shown in Fig. 2.

The use of GA in optimization is focused in four basic choices: coefficients, rules, rule-base structure, and total optimization. This problem was raised with coefficients to establish the alternatives configuration.

Initial investment:	Unit	Quantity	Cost per unit (MXN)	Total Cost (MXN)
Ewes	heads	127	5,000.00	635,000.00
Rams	heads	6	9,000.00	54,000.00
Land area (with body of water)	m^2	40863	5.00	204,316.83
Hammer mill	unit	1	18,000.00	18,000.00
Forage grinder	unit	1	12,500.00	12,500.00
Shed	m^2	133	150.00	19,950.00
Lambing shed	m^2	12	150.00	1,800.00
Sheep keeper's house	m^2	48	350.00	16,800.00
Medium duty truck	unit	1	381,600.00	381,600.00
Barbed wire	m	809	1.36	1,100.58
Barbed wire staple	Kg	2	25.00	56.15
Total Initial investment				1,345,123.56
OPERATING EXPENSES STATEMENT				
Feedstock:				
Food	Kg	133	1,377.60	183,220.80
Minerals and salts	Kg	133	1,000.00	133,000.00
Total feedstock costs				316,220.80
Labor costs:				
Sheep keeper salary	days	365	80.00	29,200.00
Veterinary fees	days	12	500.00	6,000.00
Machinery technical expert fees	days	2	400.00	800.00
Butcher fees	heads	0	65.00	-
Total labor costs				36,000.00
General expenses:				
Variables costs				
Vaccines	dose	133	10.00	1,330.00
Antiparasitic remedies	dose	133	14.00	1,862.00
Vitamins and supplements	dose	133	16.00	2,128.00
Fixed costs				
Hammer mill depreciation			1,200.00	1,200.00
Forage grinder depreciation			1,041.67	1,041.67
Supplies and maintenance of machinery (replacement parts, grease, etc.)			366.67	366.67
Total general expenses				7,561.67
Total operating expenses				359,782.47
COSTS OF GOODS SOLD STATEMENT				
Petrol	litres	2000	6.13	12,260.00
Vehicle depreciation			38,160.00	38,160.00
Mechanic labor fees	days	2	250.00	500.00
Maintenance supplies of the vehicle (engine oil, spark plugs, etc.)			1,833.33	1,833.33
"Tenencia" tax		1	9,417.47	9,417.47
"Verificación" tax		2	437.00	874.00
- Total operating expenses				359,782.47
Total costs of goods sold				422,827.27
INCOME STATEMENT				
Sales revenue				
Ewes	heads	0	63.67	-
Rams	heads	0	63.67	-
Lambs	heads	0	63.67	-
Total sales revenue				-
- Total costs of goods sold				422,827.27
Gross profit				(422,827.27)
Net income (loss)				(422,827.27)

Fig. 1. Outline to estimate initial investment and cash flows.

--*Stage 5: To calculate a value measure.* Every time the pseudo-random samples were generated through the GA, the results statements were produced and the NPV was calculated with the MARR chosen.

--*Stage 6: To describe a value measure.* The results obtained from the simulations were analyzed.

--*Stage 7: Conclusions.* This step depended on the GA application in the economic evaluation process and the results obtained in such process, which determined the best alternative and variables coefficients.

Fig. 2. Genetic algorithm general structure.

I. Results

The NPV optimization results using a GA run with different crossover and mutation indexes are presented in Table II, where the number of runs performed is shown in the first column. The second column indicates the best value found in the function which was optimized, for this study the maximum NPV. The next 4 columns correspond to the setting that produced the best values in each run. Finally, the last 2 columns show the crossover and mutation indexes used in each run.

According to the obtained results, the best one was identified with the setting of run No. 3, which corresponded to the variables 10-year planning horizon, 127 ewes as initial number, Suffolk breed, and a carcass type of sale. From these results, the other variables values for the investment decision making were able to be estimated: 6 rams as initial number and 40,863 m^2 of land area required.

Profitability speaking, if the initial investment is carried out as recommended, with 25% MARR and 10-year planning horizon, the NPV estimated would be MXN 22,533,867.59.

II. Conclusions

The assessment of an economic project such as the profitability of fattening-sheep farming, involves a relatively complex structure for its optimization, when uncertain parameters are considered.

The objective of this work was based in the maximized NPV non-lineal function, and involved the farming process simulation to estimate cash flows. Using different scenarios where the initial number of sheep was changed (therefore the space requirements also varied), the initial investment was estimated.

Using Monte Carlo simulation, the sheep population was estimated in a yearly basis, as well as the sales and the farming and trading costs, analyzing the uncertain factors through probability distributions.

Based on the results obtained, applying a GA the investment decision making could increase the profitability of a sheep farming project.

The best NPV estimated for this analysis was obtained from the setting: 10-year planning horizon, 127 ewes as initial number, Suffolk breed, and a carcass type of sale.

These results have a coherent behavior in view of the fact that Suffolk is an expensive type of breed (observed in the initial investment); nevertheless its high price is rewarded by its high carcass yield, having as a premise that the carcass sale is better paid in the market than "on-the-hoof" sale.

Appendix

A. *Glossary*

--Sheep: Singular and plural general name to refer lambs, ewes, rams, and wethers as a whole.

--Lamb: A sheep either male or female younger than one year.

--Ewe: A female sheep older than one year.

--Ram (occasionally called tup): A male sheep older than one year.

--Wether: A castrated male sheep older than one year.

--'On-the-hoof' type of sale: Sheep are sold by weight without any further process.

--Carcass type of sale: Sheep are slaughtered to produce meat, obtaining about 50 % of the live animal weight.

--Semi-extensive system: Sheep are tended during the day and they get supplementary food in feeding troughs at the end of the afternoon.

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TABLE II
RESULTS USING GENETIC ALGORITHMS

Run	Best NPV (MXN)	Planning Horizon	Initial Number of Ewes	Type of Breed	Type of Sale	Mutation Index	Crossover Index
1	22,222,168.21	9	127	Suffolk	Carcass	0.1	0.5
2	22,165,510.65	9	127	Suffolk	Carcass	0.1	0.7
3	22,533,867.59	10	127	Suffolk	Carcass	0.1	0.9
4	22,287,097.17	9	127	Suffolk	Carcass	0.3	0.5
5	22,152,817.68	9	127	Suffolk	Carcass	0.5	0.5

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