# Hatchery Production Optimisation Using Monte Carlo Approach

*Temitayo A. Ewemoje[1]. and Olusegun S. Ewemooje[2].
[1]Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan, Ibadan, Nigeria
e-mail: ta.ewemoje@mail.ui.edu.ng tayo_ewemoje@yahoo.co.uk

[2]Department of Statistics, Faculty of Science, University of Ibadan, Ibadan, Nigeria
e-mail: sunsege@yahoo.com

*Corresponding author

## ABSTRACT

Optimization of hatchery production processes was carried out using the Monte Carlo method. In the economics of engineering decisions with the objective of the investor identifying an optimum solution, an investor chooses his or her optimal solution from the set of scenarios that offer maximum expected return for varying levels of risk. Outcomes associated with these random numbers are then analysed to determine the likely results and the associated risks. Taking a major day old hatchery as a case study, data were obtained from the daily production spreadsheet for a period of six years (2003-2008). Excel spreadsheet was used in simulating 6,631 iterations for each day old chick production quantity. Hatching 45000 fertile eggs always yields the largest expected profit when compared with the profit margin of hatching 5000, 15000, 25000, or 35000 fertile eggs. Therefore, it appears as if hatching 45000 fertile eggs is the optimum production decision. Producing below the optimum production quantity, the mean profit obtained is very much lowered compared to the mean profit of the optimum 45000 production quantity. Also, production risks are higher below the optimum 45000 production quantity. This situation implies underutilization of the hatchery production system.

**Keywords:** Optimum production, Profit, Risk analysis, Iterative solution, Monte Carlo

## 1.0 INTRODUCTION

Numerical methods that are known as Monte Carlo methods can be loosely described as statistical simulation methods, where statistical simulation is defined in quite general terms to be any method that utilizes sequences of random numbers to perform the simulation. Monte Carlo methods have been used for centuries, but only in the past several decades has the technique gained the status of a full-fledged numerical method capable of addressing the most complex applications. Monte Carlo simulation studies are often used for methodological investigations of the performance of statistical estimators under various conditions. They can also be used to decide on the sample size needed for a study (Kochanski, 2005). Monte Carlo studies are sometimes referred to as mathematical technique that allows people to account for risk in quantitative analysis and decision making (Peters and Marmorek, 2001). Hence, the combination of these quantitative variables/parameters governing a particular system and its interactions to obtain the most efficient and profitable system is termed optimisation. In other words, varying multiple parameters simultaneously based on underlying probability distributions of the parameters is termed the traditional Monte Carlo simulation (Ma et al., 2000; Tiscareno-Lopez et al., 1993, 1994).

Sustainability and profitability of farm enterprises depend heavily on good management practices and capabilities to adapt to technical, economical and social changes. Unlike the rather stable context of the past decades, farmers must now strive for a dynamic competitive advantage that requires a thorough understanding of their production processes so as to control them under various constraints and towards specific objectives, both of which may change from one year to the other (Cros et al., 2002). Risk perception of how people think about risk, communicate risk, transmission of information about risk and its management differ in different fields (Parsons, et al., 2005); hence, taking decisions in uncertainty to control risk to an acceptable level differs. Because people differ in their attitude to risk management, it is unlikely that the same amount of experimentation will be optimal for all situations as different farmers attach differing weights to the expected profit and risk levels of any production process (Anderson and Dillon, 1968).

A conceptually simple and a straightforward statistical approach to the solution of differential-systems with random initial conditions is the Monte Carlo method (Sobel, 1994). In this method a sample size is generated on the computer and the corresponding system of equations is solved. This procedure is repeated several times and finally the mean values, the variances, and probability density functions of the system output can be estimated using common statistical techniques. Major drawbacks of the Monte Carlo method are the large number of repetitive simulations necessary to obtain an acceptable level of accuracy and the fact that sample must be completely specified in a probabilistic sense, i.e. should be known (Scheerlinck et al., 2003)

## 1.1 OBJECTIVES

To determine the optimum hatchery production using Monte Carlo approach, impact of risk in managerial decision on production output, probabilities of uncertain events that might influence hatchery production output positively or negatively.

## 2.0 METHODOLOGY

Data from the production and sales record of a major day old hatchery point at Oluyole Industrial estate Ibadan was used as a case study, the data were obtained from the daily production spreadsheet of the hatchery production for a period of six years spanning the years 2003 to 2008. The data retrieved were only for the hatchery production of day old chicks (layers and cockerels) among other hatchery livestock production such as broilers, fishes and turkeys.

**2.1 Determining the Number of Iterations:** Random numbers are generated according to probabilities assumed to be associated with a source of uncertainty in any production process. The Monte Carlo provides an estimate of the expected value of a random variable and also predicts the estimation error which is proportional to the number of iteration thus;

The total error is given by: $\varepsilon = {}^{3\sigma}\!/\!_{\sqrt{N}}$ ...(1)

σ is the Population Standard Deviation (STDEVP) of fertile eggs given as

σ = STDEVP(B2:B541,AVERAGE(B2:B541)) ...(2)

N is the number of actual iterations. Thus to achieve a 50% error reduction i.e. a 50% increase in accuracy, the standard error reduces only at the rate of the square root of the sample size ($i.e.\sigma / \sqrt{n}$). Hence to determine the number of iterations for an error of less than 2%; an absolute error of 2%

ε = AVERAGE(B2:B541)/50 ...(3)

**2.2 Monte Carlo Simulation:** Monte Carlo simulation was used as a tool to determine the probabilities of fertile eggs and good chicks; these are given by the following discrete random variables in table 1 below. In assigning the associated probabilities, we first sort out number of observations that falls into each of the possible fertile eggs ranges by using "COUNTIF" as follows: =COUNTIF("<=10000"), =COUNTIF(">=10000")-COUNTIF(">20000"), =COUNTIF(">=20000")-COUNTIF(">30000"), =COUNTIF(">=30000")-COUNTIF(">40000"), =COUNTIF(">=40000")-COUNTIF(">50000"). These ranges are denoted by their mid-point as follows 5000, 15000, 25000, 35000 and 45000 respectively. The corresponding number of observations was 113, 241, 122, 51 and 13 respectively and the sum total was 540. Each value of the number of observations was then divided by the total number of observations to arrive at the probability for each possible fertile egg. Hence, for possible fertile eggs of 5000 we have (113/540) 0.21. Therefore probability values for each possible fertile eggs of 5000, 15000, 25000, 35000 and 45000 gave associated probabilities of 0.21, 0.45, 0.23, 0.09 and 0.02 respectively. Similar procedure was repeated to arrive at the associated probabilities values for possible good chicks.

**Table 1: Probable Good Chicks from Fertile Eggs and Associated Probabilities**

| Fertile Eggs | probability | Good Chicks | Probability |
|---|---|---|---|
| 5000 | 0.21 | 3500 | 0.17 |
| 15000 | 0.45 | 10500 | 0.35 |
| 25000 | 0.23 | 17500 | 0.29 |
| 35000 | 0.09 | 24500 | 0.13 |
| 45000 | 0.02 | 32500 | 0.07 |

In this Monte Carlo experimentation, the following possible good chicks were simulated; 3500, 10500, 17500, 24500 or 32500 obtained from possible fertile eggs of 5000, 15000, 25000, 35000 or 45000 (Table 1). Then it was determined which quantity yield the maximum average profit over the 6631 iterations. On the computer, keyboard F9 was pressed many times (say 6631 times) for each fertile egg and tallied up the expected profit for each fertile egg. Each time the F9 button is pressed, the random numbers are recalculated. This situation is one in which a two-way data table comes into play. Computation of average simulated profit for each fertile egg quantity and standard deviation of the simulated profits for each order quantity was done.

## 3.0 RESULTS AND DISCUSSION

Population Standard Deviation (σ) of fertile eggs and the estimation error (ε) from equations 2 and 3 were given as 9549.63 and 351.83 respectively. Substituting these values in equation 1 gave the actual number of iterations as 6630.72. However, we approximate this to 6631 iterations.

The formulae for random number generation [RAND()] was entered in cell C2 and a number that is equally likely to assume any value between 0 and 1 returns for different iteration runs. 0.848339 was observed for the table 2. For the 6631 iterations, the random number generation function (F3 to F7) was associated with each value of possible good chicks (G3 to G7) while the random number generation function (H3 to H7) was associated with each value of possible fertile eggs incubated (I3 to I7) respectively. This association implies that 5000 fertile eggs incubation will occur less than 21 percent of the times and this will correspond to a hatch of 3500 good chicks occurring less than 17 percent of the times.

In this simulation, random number was used to key a lookup from the table 2 with the range F3:I7. Random numbers greater than or equal to 0.17 and less than 0.52 corresponds to 10500 fertile eggs while random numbers greater than or equal to 0.21 and less than 0.66 corresponds to 15000 good chicks hatch. The profit accrued from the 6631 iterations of resulting good chicks hatched from the 5000 fertile eggs incubated are then generated by copying from B16 to B17:B6646 in table 2 and similar simulation results were obtained for the 6631 iterations of resulting good chicks hatched when 15000, 25000, 35000 or 45000 fertile eggs were incubated.

A random number in cell C2 with the formula "=RAND()" was created. Good chicks was simulated for the hatchery under consideration in cell C1 with the formula VLOOKUP(rand,lookup,2) and also simulated fertile eggs in cell C3 with the VLOOKUP formula. The unit production cost in cell C4 was #94.43 and unit sale price in cell C5 was given as #131.90 in table 2. Revenue was computed as the product of good chicks' quantity and unit sale price in cell C7 and total cost as the product of fertile eggs quantity and unit production cost in cell C8 respectively. Finally in cell C9, profit was computed as the difference between revenue and total cost.

Profit for each iteration number 1 through 6631 was calculated for each good chick quantity. In cell B14, average simulated profit for each good chick quantity was calculated by the formula AVERAGE(B16:B6646), then the cells B13 to C13:F13 was copied. By copying the formula STDEV(B16:B6646) from cell B14 to C14:F14, standard deviation of simulated profits for each quantity was computed as shown in table 2.

**Table 2: Monte Carlo Simulation in MS Excel Spreadsheet**

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | GoodChicks | 24500 | | | | | | |
| 2 | | rand | 0.848339 | | | | | | |
| 3 | | FertileEggs | 25000 | | | 0 | 3500 | 0 | 5000 |
| 4 | | UnitProdCost | 94.43 | | | 0.17 | 10500 | 0.21 | 15000 |
| 5 | | UnitSalePrice | 131.9 | | | 0.52 | 17500 | 0.66 | 25000 |
| 6 | | | | | | 0.81 | 24500 | 0.89 | 35000 |
| 7 | | Revenue | 3231550 | | | 0.94 | 32500 | 0.98 | 45000 |
| 8 | | TotalCost | 2360750 | | | | | | |
| 9 | | Profit | 870800 | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | mean | -1003456 | 311698.7 | 1629132 | 2963512 | 4271120 | | | |
| 14 | Std Dev | 897651 | 901149.8 | 912654.2 | 893883 | 898906 | | | |
| 15 | 870800 | 5000 | 15000 | 25000 | 35000 | 45000 | | | |
| 16 | 1 | -756950 | -382250 | 2825350 | 2255750 | 3574750 | | | |
| 17 | 2 | 187350 | 562050 | 936750 | 3200050 | 5463350 | | | |
| 18 | 3 | 187350 | 1506350 | 936750 | 2255750 | 4519050 | | | |
| 19 | 4 | -756950 | 562050 | 2825350 | 3200050 | 4519050 | | | |
| 20 | 5 | -756950 | -1326550 | 936750 | 3200050 | 4519050 | | | |

Each time F9 was pressed, 6631 iterations of profits accrued from good chicks hatched were simulated for each possible production quantity. Observations from table 2 showed that hatching 45000 fertile eggs always yields the largest expected profit when compared with the profit margin of hatching 5000, 15000, 25000, or 35000 fertile eggs. Therefore, it appears as if hatching 45,000 fertile eggs is the optimum production decision.

Analysing the risk involved in the hatchery production, if 35000 fertile eggs were hatched instead of hatching 45000 fertile eggs our expected profit drops approximately 31 percent, but our risk as measured by the standard deviation of profit drops by 0.6percent. Therefore, if we are not extremely risk adverse, hatching 35000 fertile eggs might not be the right decision. However, hatching 5000, 15000, 25000 or 45000 instead of 35000 the risk rises by 0.4%, 0.8%, 2.1% or 0.6% respectively. Hence, we cannot consider hatching below 35000 fertile eggs in this hatchery to have an optimum production.

## 4.0 CONCLUSIONS

The risks associated with the hatchery production of quantity below or above the optimum production quantity are such that:

- Producing below the optimum production quantity, the mean profit obtained is very much lowered compared to the mean profit of the optimum 45000 production quantity. Also, production risks are higher below the optimum 45000 production quantity. This situation implies underutilization of the hatchery production system.

- Producing above the optimum production quantity, the mean profit obtainable may be lowered compared to the mean profit of the optimum production quantity. Producing above optimum production quantity, higher production costs may results and the mean profit obtainable would not compensate for higher production cost.
- However it is worth nothing that the six years day old chicks production data obtained from the commercial hatchery did not exceed 45000 production quantities, hence extrapolating beyond this value might introduce large magnitude errors.

## 5.0 REFERENCES


Anderson, J. R. and Dillon, J. L., 1968. Economic Considerations in Response Research. American Journal of Agricultural Economics, Vol. 50, No 1; Pp 130-142. Retrieved 21st December 2009 from http://www.jstor.org/stable/1237876

Cros M. J., Garcia F., Martin-Clouaire R. and Rellier J. P., 2002. Modeling and Simulating Agricultural Production Processes. ASAE Meeting Paper No. 02-3037. St. Joseph, Mich.: ASAE.

Kochanski, G., 2005. Monte Carlo Simulation. Retrieved on 24th September 2008 from http://kochanski.org/gpk/0401Oxford

Ma, L., Ascough II, J. C., Ahuja, L. R., Shaffer, M. J., Hanson, J. D. and Rojas, K. W., 2000. Root Zone Water Quality Model Sensitivity Analysis using Monte Carlo Simulation. *Transactions of the ASAE* 43(4): 883-895.

Parsons, D. J., Orton, T. G., Souza, J. D., Moore, A., Jones, R. and Dodd, C. E. R., 2005. A Comparison of Three Modelling Approaches for Quantitative Risk Assessment Using the Case study of *Salmonella spp.* In Poultry Meat. *International Journal of Food Microbiology, 98: 35-51.* www.elsevier.com/locate/ijfoodmicro

Peters, C. N. and Marmorek, D. R., 2001. Application of Decision Analysis to Evaluate Recovery Actions for Threatened Snake River Spring and Summer Chinook Salmon *(Oncorhynchus tshawytscha). Can. J. Fish. Aquat. Sci. 58: 2431–2446. DOI: 10.1139/cjfas-58-12-2431*

Scheerlinck N., Peirs A., Desmet M., Clauwers S. and Nicolai B. M., 2003. Numerical Solution of the Fokker-Planck Equation for Postharvest Applications. ASAE Paper No. 033099. St. Joseph, Mich.: ASAE

Sobel, I.M., 1994. A primer for the Monte Carlo Method. 107 pages. CRC Press, Inc., Boca Raton, Florida, USA.

Tiscareno-Lopez, M., Lopes, V. L., Stone, J. J. and Lane, L. J., 1993. Sensitivity analysis of the WEPP watershed model for rangeland applications I. Hillslope processes. *Transactions of the ASAE* 36(6): 1659-1672.

Tiscareno-Lopez, M., Lopes, V. L., Stone, J. J. and Lane, L. J., 1994. Sensitivity analysis of the WEPP watershed model for rangeland applications II. Channel processes. *Transactions of the ASAE* 37(1): 151-158.