Original Research Article

Application of Markov Chain analysis in forecasting future farm size in Grasscutter production in Osun State, Nigeria

ABSTRACT

Aim: The study examined the prospects and challenges of Grasscutter production with a view to determining among other things the profitability and projecting the future farm size of its production in the study area.

Study Design:

Place and Duration of Study: The study was carried out in Osun State, Nigeria between year 2016 and 2017.

Methodology: Primary data were collected through a well-structured questionnaire administration from the three agricultural zones in the State. Twenty four Grasscutter farmers each were randomly selected from each of the agricultural zones. Data were collected on demographics of grasscutter farmers, production activities in terms of inputs, outputs and their respective prices for the years 2016 and 2017. Data were analyzed through descriptive statistics, Markov chain, Gross margin and Regression.

Results: The study revealed that male respondents (85%) dominated Grasscutter production in the study area while the mean age of respondents was 43 years. Majority (97%) of the respondents had formal education with an average grassutter farming experience of 11 years while the mean flock size was 2.5 colonies. The gross margin results showed that grasscutter production had a profit margin of ₦11,333.33/respondent/month. The mean grasscutter farm size revealed an upward trend in farm size until the year 2025 and thereafter stabilizes at about 3.3 colonies of grasscutter farm size. The correlation analysis showed significant relationship between gross margin and level of education and farming experience with r-values of 0.817 and 0.697 respectively and p-values of 0.005 and 0.002, respectively, which makes the null hypothesis to be accepted. The regression analysis has R^2 value of 0.659.

Conclusion: Grasscutter production, though in small scale, is profitable in the study area. About (66%) variation in the dependent variable is explained by the independent variables and the grasscutter farmers in the study area have great potential to boost local production

Key words: Equilibrium, Gross margin, Grasscutter farmers, Markov Chain, Profitability.

1.0 INTRODUCTION

The shortage of animal protein in the third world countries can be ameliorated by improving the existing conservation programme of wildlife particularly the domestication of rodents that are tractable, prolific and widely accepted to the public for consumption [1]. Captive breeding of game species as a possible way to satisfy local demand without compromising the wild stock has also been recommended by several authors [2].

Wildlife domestication according to [3], has been suggested as a possible way of improving meat supply and eliminating the threat of extinction due to poaching of some species of wild animals in Nigeria. The species advocated include: grasscutter (*Thryonomys swinderianus*), guinea fowl and the giant African snail. Among these aforementioned, grasscutter (cane rat) is the most preferred [4]. Usually, cane rats live in small groups of family colonies, comprising a buck (male), one or more does (females) that live with their offspring. A colony on the average is usually between 1 – 5 grasscutters in the ratio 1 male to four females, where five is the optimum. Only males live solitarily [5]. [6] asserted that unlike some animals which may not be killed or touched because of religious dictates, traditional taboos or prejudices, the grasscutter meat transcends religious prohibitions and Muslims who do not consume rabbit or pig are known to consume grasscutter. The high demand for grasscutter meat and the economic benefit that accrues from its sale has resulted in aggressive hunting with complete disregard for conservation of the species and the environment [6].

The grasscutter meat is a favourite one and accounts for the greater proportion of bush meat sold in West Africa. They are robust animals measuring up to 60cm (head and body) and weighing more than 9kg. Grasscutter is a wild hystricomorphic rodent hunted aggressively for its excellent taste and higher nutritional value when compared to other species of livestock and it does not require imported raw materials to survive [7]. [7] stated that Grasscutter has high protein content (19- 23%) and contains less fat than most domestic animals. Beef, lamb and pork contain higher fat percentage than meat from the grasscutter. Grasscutter meat is nutritionally superior to those of domestic animals like sheep or goat because of its high protein to fat ratio and higher mineral contents couple with the fact that the meat quality is also leaner and non-cholestrogenic [8].

Domestication of grasscutter does not require much land and can even be raised in a small confined area of land. Therefore in situations where agricultural land is scarce or unavailable, micro livestock such as the grasscutter whose meat is generally preferred to conventional meat could be developed.

However, many changes have taken place in the structure of livestock production in Nigeria, most especially, in Osun State, over the past 20 years. The total number of livestock farms has been declining steadily, and the size distribution of those farms remaining in production has undergone significant change [3]. [2] opined that from 1995 to 2013, farm numbers declined by nearly 50% and considerable shifts occurred in the size distribution of the remaining farms. Hence, this to a large extent accounts for the low supply of the product relative to high demand for its meat; thus necessitating the determination of the socio-economic factors and constraints influencing its production size and to project future farm size with a view to determining what the future holds for the enterprise in the study area. It is also necessary to take another look at the grasscutter production in terms of costs and returns in order to determine the profitability and the possibility of producing grasscutter commercially particularly under the prevailing economic conditions.

1.1 THEORETICAL CONSIDERATIONS

Markov chain process is one of the probabilistic models used in the analysis of economic observations when particular time-ordered data are available [9]. A finite Markov process is a stochastic process in which the outcome of a given trial (experiment) in the time (t + 1) essentially depends on the outcome of the trial in the preceding time period (t) and this dependence holds at all the various stages of the trial. Due to the fact that economists are often interested in characterizing or summarizing how economic processes and institutions have changed through time as well as that paths they are likely to take in future time periods, finite Markov Chain analysis was employed in this study to analyze and predict the trend in mean and median farm size of cotton farms. This process is determined by specifying given set of states (S_1, $S_2 \ldots S_n$). The process can be in one and only one of these states at a given time and it moves successively from one state to another. Each move is called a step. The probability that the process moves from Si to Sj depends only on the state Si that is occupied before the step. The transition probability that the process will move from Si to Sj is given for every pair of states. Also, an initial starting point state is specified at which the process is assumed to begin. The transition probabilities P_{ij} can be represented in the form of transition matrix P

$$P = \begin{pmatrix} & S_1 & S_2 & \ldots & S_n \\ S_1 & P_{11} & P_{12} & \ldots & P_{1n} \\ S_2 & P_{21} & P_{22} & \ldots & P_{2n} \\ \vdots & \vdots & \vdots & & \vdots \\ S_n & P_{n1} & P_{n2} & \ldots & P_{nn} \end{pmatrix}$$

P_{ij} denotes probability of moving from S_i to S_j in the next step. Since the element of this matrix are non-negative, and the sum of the elements in any row is one, the matrix (P) is a vector, completely defines a Markov chain process, that is given this information, the outcome of say the n^{th} step, can be determined. The main distinguishing feature of a Markov process is that it is concerned with the probabilities of being in various states at any time and for moving from one state to another.

Assuming there are N farmers in the study area belonging to different categories of farmsizes. Farmers are put into categories based on farm size (colony) of grasscutter reared. Grasscutter farm sizes were grouped as follows:

Farm sizes (colony :1 male : 4 females grasscutters) per farmer was grouped such that;

1 - 5 ≡ S_1 11 - 15 ≡ S_3 21 - 25 ≡ S_5

6 - 10 ≡ S_2 16 - 20 ≡ S_4 26 - 30 ≡ S_6 and so on.

At a given period 't' the N farmers may belong to a certain number of categories S_i (where, i = 1, 2, 3…m) with each category containing n_1, n_2… n_m, such that $n_1 + n_2 + \ldots + n_m = N$. The data on the behaviour of this N farmers for another time period 't + 1' were collected.

For this study 't' and 't + 1' were years 2016 and 2017 respectively. During the interval between the time periods, the n_i farmers belonging to the first categories 'S_i' during the first period might have moved to a higher or lower category or remained in the same category. The probability that any farmer in the first category in period 't'moves to another category during the second period't + 1' is given by;

$$P_{ij} = \frac{n_{ij}}{n_i} \quad (j = 1, 2, 3, - - -, m) \ldots\ldots\ldots (1)$$

However, constraints on elements of the probability transition matrix, P, are that the probabilities in each row should add up to 1 and that $P_{ij} \geq 0$ (for all i and j). Thus, it implies that P is a stochastic matrix. This matrix, P, together with an initial starting state completely defines a Markov chain process, that is, given this information, we could determine the outcome of, say, the $(t + i)^{th}$ step/ period.

Let $P^{(0)} = ({}^{P1}/M, {}^{P2}/M \ldots\ldots\ldots P^m/M)$ = initial proportion of farmers in the S_i (i = 1, 2, 3 … M) states at time 't', i.e. starting state or initial state or initial vector (probability vector)

Where $\quad P_j = \frac{n_j}{N}$

N is the proportion of farmers in the j^{th} category. Hence, with this information, the future path of the stochastic process is given by;

$P^{(0)} P = P^{(1)}$ state vector in time, t + 1

$P^{(1)} P = P^{(2)}$ state vector in time t + 2

$P^{(m-1)} P = P^{(m)}$ state vector in time, t + m……………………………………………………………………..(2)

Alternatively, $W^{(m)}$ may be written as $P^{(m)} = P^{(0)} P^m$ ……………………………………………....... (3)

$W^{(m)}$ is the probability vector at each intervening period state.

Hence, [10] contended that given a regular stochastic matrix, P, there exists an m x m matrix, $P^{(e)}$, to which P^m will converge as $m \to 0$ consisting of m rows which are exactly alike. That is, as the number of stages or transitions approaches infinity, Markov Chain approaches a steady equilibrium state in which the probability distribution of its states approaches stationarity.

Therefore, $P^{(0)} P^{(e)}$ gives the fixed probability vector, or equilibrium probability vector W(e) of the stochastic process.

Hence: $P^{(m)\to} P^{(e)}$ as $m \to \infty$

$P^{(o)} P^{(e)} = P^{(e)}$

$P^{(e)} P = P^{(e)}$ ………………………………………………………………………………………………… (4)

Equilibrium in this sense does not imply that there is no movement of farmers between categories, but that on the average, the proportion of farmers entering a given category per period is equal to the average proportion leaving it. Those interested in a more rigorous discussion of Markov chain analysis should consult Judge and Swanson (1961).

Hence, the structure of the grasscutter farm size for the respondents in the study area, provided the factors and conditions currently influencing farm size continue through time, was projected up to the equilibrium year.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Osun State comprising thirty Local Government Areas and three agricultural zones, namely: Iwo, Osogbo and Ife-Ijesa respectively. The State is located in the South-West geopolitical zone of Nigeria and occupies an area of land of about 14, 875km^2. The ecological conditions are conducive for an impressive diversity of livestock such as cattle, sheep, goat, pig, rabbit, grasscutter and poultry. The State has a population of about 3.5 million [11] and the vegetation is characteristically that of rain forest and derived savannah with a mean annual rainfall that varies between 980mm and 2800mm and a temperature range of 27 - 32^{o}C.

2.2 Method of Data Collection

Primary data were collected through a well-structured questionnaire administration from the three agricultural zones in the State. Resident agricultural extension agents and the State Ministry of Agriculture, Osun, were contacted to provide the list of grasscutter farmers which formed the sampling frame for the study. Twenty four grasscutter farmers each were randomly selected from each of the agricultural zones. Data collected include socio-economic characteristics of farmers and farms, production activities in terms of inputs, outputs and their respective prices for the years 2016 and 2017.

2.3 Sample Size/Sampling Techniques

The sample size was computed according to [12] from the population of interest.

$$n = \frac{Z^2 \delta^2}{e^2}$$

Where n is the sample size, Z is the standard deviation at a confidence interval (Z-value), e is the margin of error and δ is the standard deviation of the population. With the assumption in this study, of z = 95%, e = 0.05%, δ = 0.20 (the standard deviation is estimated from other studies).The study used

95% level of confidence (Z= 1.96) and e = 0.05 (allowable error the researcher is willing to accept). The sample was

$n = 1.96^2 * 0.20 * 0.20 \div 0.05^2 = 62$

This gives sample size of 62 respondents but other additional 10 included to cater for non- response and spoilt questionnaires. Hence, a total of 72 questionnaires were administered to established grasscutter farmers in the study area.

2.4 Method of Data Analysis

Data collected were analyzed using the following tools: Descriptive statistics, Markov Chain process, Gross Margin, Correlation and regression. Descriptive statistics such as frequency distribution and percentages were used to analyse data on socio-economic characteristics. Markov Chain was used to analyse and project the future farm size while Gross margin analysis was used to estimate costs and returns of grasscutter farmers. The Gross margin (GM) represents the difference between Total Revenue and Total Variable Costs.

$$GM = TR - TVC \quad \ldots\ldots(5)$$

Correlation analysis was used to determine the relationship between socio-economic characteristics of respondents and the profits derived from grasscutter production. The regression model was used to determine the relationship between profitability and other variables. The model was tested using different functional forms.

The stated equation for the model is: $Y = \beta_o + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + \varepsilon_i$

Where; Y = Profit, X_1 = Sex, X_2 = Educational level, X_3 = Years of experience, X_4 = Reason for raising grasscutter, X_5 = Area of specialization and ε_i = Error term.

3.0 RESULTS AND DISCUSSION

The results of the socio-economic characteristics and some management practices of the respondents are presented in Table 1. If old farmers are defined as those who are above 50 years of age, then, 27.8% of the grasscutter farmers in the study area can be said to be old. The mean age of the respondents was 42.7 and 72.2% of the farmers are within the age range 41 – 50 years. This implies that young people engage in grasscutter farming business than older people and hence represents a high percentage of grasscutter farmers in the study area. The Table further shows that (84.7%) of the respondents were male thus showing the dominance of male farmers in grasscutter production in the study area. This agrees with [8] that females engage mostly in marketing; while males do most of the production processes. In addition, (97.2%) of the respondents had formal education ranging from primary to tertiary. Thus, the literacy level of the respondents is very high and this implies that grasscutter farming requires certain level of education in terms of management to ensure productivity.

The mean years of experience in grasscutter farming was 11 years thus implying that majority of the farmers had a relatively few years of experience in grasscutter farming. Experience according to [13] provides the farmers with insights on how to militate against risk and possible losses since they have become acquainted with them. It was further revealed that the average farm size of grasscutter reared per respondent was 2.5 colonies while the average litter size per kindling was 4. Majority (59.7%) of the respondents were civil servants while majority (58.3%) sourced their capital from cooperative societies. Table 1 also reveals that family labour (68%) was the predominant labour type in the study area. The modal grasscutter farm size (45.8%) was 2 colonies while majority (47%) of the respondents depend on concentrates in feeding their animals. Furthermore, (62%) and (65%) of the respondents had extension contacts and training in grasscutter production, respectively. It is believed that extension contacts and training afford farmers the opportunity to learn and improve their knowledge of grasscutter production.

Table 1: Selected socio-economic factors /management practices of respondents N = 72

Parameters	Frequency	Percentage (%)	Parameters	Frequency	Percentage (%)
Age (Years)			**Major occupation**		
41 – 50	52	72.2	Farming	11	15.3
51 – 60	11	15.3	Artisans	18	25
61 - 70	9	12.5	Civil Servant	43	59.7
Gender			**Types of Labour**		
Male	61	84.7	Family	49	68
Female	11	15.3	Hired	10	13.9
Educational Level			Both	13	18.1
No formal Education	2	2.8	**Extension Contact**		
Primary Education	7	9.7	Yes	62	86.1
Secondary Education	22	30.6	No	10	13.9
Tertiary Education	41	56.9	**Training**		
Grasscutter rearing experience			Yes	65	90.3
1 - 5	23	31.9	No	7	9.7
6 – 10	39	54.2	**Farm size (Colony)**		
11 – 15	10	13.9	1	11	15.3
Litter size per kindling			2	33	45.8
1 ≤ 5	52	72.2	3	19	26.4
6 ≤ 10	20	27.8	4	9	12.5
Sources of fund			**Types of feed**		
Personal savings	11	15.3	Concentrates	35	48.6
Friends and relatives	5	7.0	Household wastes	6	8.3
Cooperatives	42	58.3	Grasses	13	18.1
Bank loans	14	19.4	All of the above	18	25.0

Source: Data analysis, 2017

3.1 Equilibrium values, actual and projected pattern of change in farm size of cotton farms

This section presents the results of the Markov chain process used in assessing and predicting the pattern of change and the equilibrium farm size of the grasscutter enterprise in the study area. The movement of cotton farmers from one farm size category to another between the two periods

(2016 and 2017) for which data were collected is presented in Table 2**.** From the transition probability matrix, the structure of farm size that would be cultivated by grasscutter farmers, if the factors and conditions currently influencing farm size of grasscutter farms continue through time was projected up to the equilibrium year. The mean grasscutter farm size revealed an upward trend in farm size until the year 2025 and thereafter stabilizes at about 3.3 colonies of grasscutter farm size. The results showed that grasscutter farmers in the study area are essentially small scale holders since the average farm size was 2.5 colonies (Table 1). The median farm size falls within 2 and 3 colonies farm size group. This implies that in the long run, at least (35%) of the farmers would have between 2 to 3 colonies of grasscutter farm size. This is far from being an economic size. When equilibrium is reached by the year 2026, about (38%) and (46%) will be between 3 and 4 colonies of grassutter farm size respectively. At equilibrium (2026), the mean cotton farm size was 3.3 colonies. This implies that about (84%) of the farmers will be within the farm size category of 3.3 colonies. When the proportions of farmers in the different farm size category at the initial year were compared with that of equilibrium values, the trend is that of a general increase from smaller farm size categories to bigger ones. For instance, at the initial year (i.e 2016), about (6%) of the cotton farmers were in the 4 colonies and above farm size categories but would have increased to about (46%) at the equilibrium year. On the other hand, about 10 percent that were in the 1 colony farm size category in 2016 would have declined to (6%) by the year 2026. On the whole, this findings show that grasscutter farming in the study area is small scale and there is a high potential to boosting local production. This finding agrees with the findings of [14] and [2]. However, their problem areas need to be looked into and promptly addressed for this potential to be fully realized.

Table 2: Annual and projected structure of farm sizes among cotton farmers

Farm size	Actual years				Projected years						
	2016	2017*	2018	2019	2020	2021	2022	2023	2024	2025	2026**
S1	0.10	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.06
S2	0.60	0.55	0.52	0.49	0.45	0.44	0.39	0.35	0.27	0.10	0.10
S3	0.24	0.29	0.32	0.34	0.35	0.36	0.37	0.37	0.38	0.38	0.38
S4	0.06	0.08	0.10	0.12	0.13	0.13	0.17	0.22	0.36	0.46	0.46
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mean	2.40	2.50	2.55	2.50	2.65	2.75	2.80	2.85	2.90	3.30	3.30

Source: Data analysis, 2017.

*Starting (initial) state probability vector

**Equilibrium probability vector

Table 3 shows the average total cost of production incurred by the respondents were ₦161,517.10k ($436.53). The total cost comprises the variable and fixed costs. From the table, variable costs represent (94.1%) while fixed costs accounted for (5.9%) of the total cost of production. Additionally, feed cost represents (15.2%), labour cost (22.3%), drugs, disinfectant and vaccines (5.3%), transportation (5.9%) and other costs (such as purchase of charcoal for warmth production) represent (7.1%) of the total cost of production. The average gross revenue was ₦288,000 per respondent per annum. The average gross margin per respondent per annum was ₦136,000 while the average Net Farm Income per respondent was ₦126,458.30k. The rate of return on investment in the study area was 83%. This implies that for every ₦1.00 invested, 83k is gained in the business. Also, the Benefit cost ratio shows that grasscutter production is a profitable business since it is greater than 1. The same thing applies to GMR (2.27). The ESR results also indicate that grasscutter production has good financial strength. The result of this finding agrees with [15]. Conclusively, the various profitability ratio techniques employed indicates that the business is profitable. Thus it is profitable to produce grasscutter in the study area.

Table 3: Average Cost and Returns of Grasscutter Production in ₦/Year

Cost/Return	**Amount (₦)**	**% of Total Cost (TC)**
Total Revenue (TR)	288,000	
Variable cost (VC)		
Cost of stocking	62,000	38.4
Feed	24,500	15.2
Labour	36,000	22.3
Drugs, vaccination and disinfectants	8,500	5.3
Transportation	9,500	5.9
Other costs(Warmth production etc)	11,500	7.1
Total variable cost (TVC)	152,000	94.1
Fixed cost (FC)		
Depreciation on Building	5518.90	
Depreciation on equipment and Machinery	3677.70	
Interest on loans	345.10	
Total fixed cost (TFC)	9541.70	
Total Cost (TC) = TFC + TVC	161,517.10	
Gross Margin(GM) = TR – TVC	**136,000.00**	

Net Farm Income (NFI) = GM – TFC	**126,458.30**	
Rate of return of investment(ROR) = NFI/TVC	83%	
Benefit cost ratio (BCR) = TR/TC	1.78	
Expense structure ratio(ESR) = TC/TR	0.56	
Gross margin ratio (TR/NFI)	2.27	

Source: Computed from field survey data, 2017.

Table 4 shows the relationships between some variables and gross margin. The correlation values for education and years of experience are significant at (5%) level. We therefore accept the Ho hypotheses for both, implying that level of education and grasscutter farming experience count in successful grasscutter production. This agrees with the findings of [16], [17] and [18].

Table 4: Correlation result of Socio-economic characteristics and profitability of grasscutter production.

Relationship	R value	P-value	Significant	Decision
Sex vs GM	-0.079	0.547	NS	Reject Ho
Education vs GM	0.817	0.005*	S	Accept Ho
Years of experience vs GM	0.699	0.002*	S	Accept Ho

*Correlation is significant @ 0.05 level. GM = Gross Margin

4.0 CONCLUSIONS

The results of the Markov chain analysis indicated an upward trend in the mean grasscutter farm size until the year 2025 and thereafter stabilizes at 3.3 colonies at the equilibrium year 2026. The trend is that of gradual increase from smaller farm size categories to bigger ones. On the whole, this finding shows that grasscutter farms in the study area is small scale and grasscutter farmers have great potentials to boost local production. The net farm income and the average rate of return on investment results showed that grasscutter enterprise in the study area, though on a small scale, was profitable and economically viable.

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