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ORIGINAL RESEARCH

Prediction of animal population dynamics with a focus on smallholder pig breeding establishments

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CEM, Conceived idea, designed study, statistical analysis, preparation of manuscript; BM, collected data & analysis, statistical analysis, preparation of manuscript

ABSTRACT

Botswana government has made efforts to diversify agriculture and pig production has been identified as one avenue to achieve this diversification in the livestock industry. It is important that farmers are encouraged to raise pigs for the purposes of creation of employment, supply of essential animal protein and consequently poverty alleviation. A Government owned Pig Nucleus Farm was therefore established at Sebele to provide good quality parent breeding stock for farmers. Farmers have used financial support offered by programmes such as the Financial Assistance Policy, Citizen Entrepreneurial Development Agency (CEDA) and Young Farmers Fund to venture into pig production. These entrepreneurs require accurate production data to guide their investments in terms of expected pig numbers that would create viable business. Pig numbers were monitored for 5, 10, 15 and 30 sow unit farms over a period of 30 weeks. Pig numbers were plotted against time and a unique mathematical equation was generated for each farm size by fitting a line of best fit in the data and selecting the equation for the line with the highest coefficient of determination. In all cases of 5, 15 and 30 sow unit farms, unique second order polynomial equations predicted the number of pigs on the farm with a coefficient of determination, R^2 = 0.805, 0.958 and 0.964 respectively. The 10 sow unit farm was predicted using a linear equation with a coefficient of determination, R^2 = 0.916. These mathematical equations for prediction of pig numbers are deemed accurate because the coefficient of determination is at least 80.5 % and some going as high as 0.964, meaning that the prediction model can explain at least 80.5 % of the variability.

Keywords Animal protein, breeding, pigs, poverty alleviation, sows.

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INTRODUCTION

Livestock production is growing rapidly the world over and this is due to the increasing demand for animal products such as meat, milk and other forms of animal protein. The greatest increase is in the production of poultry meat and pigs, as well as eggs and milk (Speedy, 2003). It is desirable to identify optimal and efficient system for the production of these animal products, the cost of which depends primarily upon the efficiency of three basic functions, namely female production, reproduction and growth of the young (Dickerson, 1970). The overall efficiency of an animal production system is measured by the ratio of total costs to total animal product (economic equivalents) from females and their progeny over a given period of time.

The Botswana Government has established low cost financial schemes such as CEDA for provision of credit to financially viable agricultural projects, and in line with this mandate, Local Enterprise Agency (LEA) has identified piggery as a sector which can diversify Botswana's agriculture (Galeboe *et al*., 2009). This has resulted in the number of pigs raised under the traditional system increasing from 4000 (CSO 2003) to 9003 (Statistics Botswana 2012) over a period of four years. A robust group of pig producers has therefore evolved in Botswana. This young industry therefore needs productive data in terms of animal numbers, floor space requirements and other aspects of pig production for the various units and systems. Animal floor space allowances are important in pork production from performance, economic and animal welfare perspective as individual pig productivity decreases as crowding increases, signifying a welfare concern (Gonyou, *et al*., 2006). Animal numbers for sustaining pig enterprise is important in an economic point of view. All this factors are vital for planning for housing, budgeting for feeding and for labour requirements.

This study examined the production of progeny in four different pig farm sizes of 5 sows denoted as Farm 1, 10 sows denoted as Farm 2, 15 sows denoted as Farm 3 and 30 sows denoted as Farm 4 over a period of 30 weeks. The Ministry of Agriculture Pig Nucleus Farm located at Sebele has good breeding stock and ideal management which include feeding and that is the reason it was chosen instead of using farmers' animals which may be fed not according to requirements. Currently there are no guidelines to inform farmers on the expected Pig populations *per* farm for four farm sizes were plotted against time and a line of best fit was generated as the mathematical model for prediction of pig population over time.

MATERIALS AND METHODS

The breeding stock was divided into five, ten and fifteen sow units and monitored for thirty weeks. Sows and boars used were mature and already in production. A thirty sow unit was developed by using the animals in the other sow units, i.e. five, ten and fifteen. At inception of the study, all sows which were not lactating were assumed to be pregnant because according to Knox and Rodriguez-Zas (2001) approximately 95% of sows express oestrus between 3 and 8 days after weaning. Suckling piglets were recorded in the population of the farm which comprised the lactating sow. Five and ten sow units were allocated one boar each, while the fifteen sow unit was allocated two boars. Data collected included actual pig numbers on the farm and number sold, the sum of which comprised the pig population at the specific time interval, and deaths were also recorded. The number of pigs on the farm was plotted against time and a line of best fit was inserted using excel software (Microsoft Office 2010), and a predictive equation for the line of best fit determined. The mathematical equation for the line of best fit with the highest coefficient of determination, R^2 was deemed the appropriate model for prediction of pig numbers for the specific farm size over 30 weeks. In a case where two different mathematical equations were generated with an equal value of R^2, the simpler equation was chosen as it is common to model with a simple equation rather than with a complex equation.

RESULTS

Pig population over a 30 week period is shown in Figure 1. The mathematical equation generated for a 5 sow unit, denoted as Farm 1 is:

$$y = 0.0136x^2 + 0.2291x + 9.4056 \qquad \text{(Equation 1)}$$

where y = pig numbers, and x is the number of weeks. The line of best fit had a coefficient of determination, R^2 = 0.8058 (Figure 1). Table 1 shows the actual pig numbers observed, the predicted pig numbers and the variation which is the difference between the predicted pig numbers and the actual pig numbers, for the 5 sow and 10 sow unit farms. In case of the 5 sow farm, the highest variation in the prediction was observed at 20 weeks where the model (Figure 1) underestimated the pig numbers by 6. At 10 and 26 weeks the model predicted the exact number of pigs on the farm (Table 1). The mathematical equation generated for the 10 sow unit, denoted as Farm 2 is:

$$y = 2.070x + 31.81 \qquad \text{(Equation 2)}$$

with a coefficient of determination, R^2 = 0.916. In prediction of pig numbers for a 10 sow unit using equation 2, the highest variation of 11 animals was observed at week 0, which is at the beginning of the study. At 10 weeks the model for the 10 sow farm predicted the exact number of pigs on the farm. The mathematical equation generated for the 15 sow farm is as shown in equation 3.

$$y = -0.067x^2 + 5.460 + 38.58 \qquad \text{(Equation 3)}$$

with a coefficient of determination, R^2 = 0.9581. In case of the 15 sow farm, the highest variation of 16 pigs underestimated was observed at week 20. The model had a closest estimate with a variation of only 1 animal at 2, 8, 12 and 30 weeks (Table 2). Prediction of pig numbers for the 30 sow farm using the line of best fit generated the polynomial equation shown in equation 4.

$$y = -0.056x2 + 7.8233x + 79.51 \qquad \text{(Equation 4)}$$

with a coefficient of determination, R^2 = 0.964. The model underestimated pig numbers at 6 weeks with a variation of 20 animals, but predicted the exact number of pigs as actual pigs on the farm at week 22 (Table 2). The coefficient of variation was 0.964.

In all cases of 5, 15 and 30 sow unit farms, unique second order polynomial equations (Equations 1, 3 and 4) predicted the number of pigs on the farm with a coefficient of determination, R^2 = 0.805, 0.958 and 0.964 respectively.

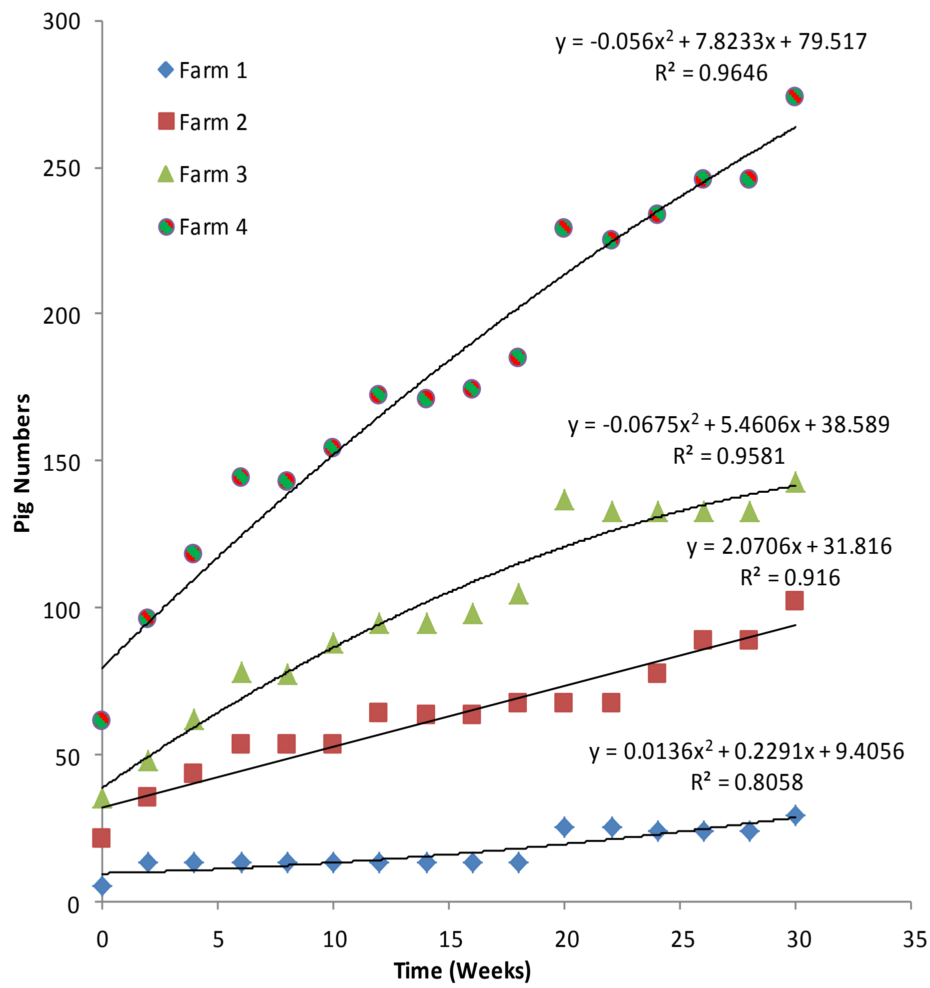

Figure 1: Pig population over a 30 week period fitted with a line of best fit for farm sizes of 5, 10, 15 and 30 sows

The 10 sow unit farm was predicted using a linear equation with a coefficient of determination, R^2 = 0.916. These mathematical equations for prediction of pig numbers are deemed accurate because the coefficient of determination is at least 80 % in all predictions with some going as high as 0.964)

DISCUSSION

The mathematical equation for Farm 1 had R2 of 0.8058 which means that the prediction model can explain 80.58 % of the variability in the data Successful predictions of pig populations for small scale pig production units of up to 30 sows with coefficients of determination as high as 0.964 implies that small scale farmers can develop informative projections of housing, feeding and labour requirements for their piggery enterprises. Pig production dynamics can assist in business projections as farmers can have information on when and how many pigs they can sell subsequent to commencement of their businesses. Farmers who seek funding for pig production from CEDA are given a grace period, which is a time past the deadline for an obligation during which a penalty that would have been imposed is waived. The animal population dynamics predictive information from the present study shall accordingly inform issues such as the grace period. Currently, CEDA guidelines for pig production stipulate a minimum stock of 100 sows. This criterion is set without much clarity on the basis of how this minimum number was derived. Therefore, based on the modalities developed for the present study, a similar study undertaken for large enterprises of up to 100 sows would inform both financiers and entrepreneurs to better determine the population dynamics of such a sow unit. Optimising economic sow

Table 1: Actual and Predicted pig numbers for 5 and 10 sow farms, over a 30 week period.

Time (weeks)	Pig Numbers, 5 sow unit			Pig Numbers, 10 sow unit		
	Actual	Predicted	Variation	Actual	Predicted	Variation
0	5	9	4	21	32	11
2	13	10	-3	35	36	1
4	13	11	-2	43	40	-3
6	13	11	-2	53	44	-9
8	13	12	-1	53	48	-5
10	13	13	0	53	53	0
12	13	14	1	64	57	-7
14	13	15	2	63	61	-2
16	13	16	3	63	65	2
18	13	18	5	67	69	2
20	25	19	-6	67	73	6
22	25	21	-4	67	77	10
24	24	22	-2	77	81	4
26	24	24	0	89	86	-3
28	24	26	2	89	90	1
30	29	28	-1	102	94	-8

herd size would be influenced by reproduction, feeding management and disease control. Pigs give high litter size than most farming animals and its gestation period is short. Therefore reproduction is an important driver of population dynamics and determinant of an economically viable sow unit. Though the present study did not evaluate reproductive performance, factors as fertility, return to oestrus and boar libido are important determinants of building herd size. Another factor is sow longevity, often an overlooked component of profitability and efficiency for commercial swine operations (Mote *et al.,* (2009). Lack of information regarding factors that influences sow herd size means that farmers desiring to build up herd size may not be able to achieve that objective. Sow longevity is determined by culling rate.

.According to Stalder *et al*. (2000) the greater the number of breeding herd replacement females needed, the greater the capital requirements for the operation, which can impair profitability. This means that it is important that sows, especially out-of-herd replacement gilts, remain in the herd long enough to achieve their profitable production potential (Rodriguez-Zas *et al.,* 2003). Contrary to this, a study by Stalder *et al*. (2000) found that females does not remain in the breeding herd in parities four, five, and six which are generally considered the peak producing parities and the time when lifetime production can greatly surpass that needed to pay for the original investment in replacement females. The present study did not last long enough to monitor effects of culling on population dynamics

Table 2: Actual and Predicted pig numbers for 15 and 30 sow unit farms, over a 30 week period

Time	Pig Numbers, 15 sow unit			Pig Numbers, 30 sow unit		
(weeks)	Actual	Predicted	Variation	Actual	Predicted	Variation
0	35	39	4	61	80	19
2	48	49	1	96	95	-1
4	62	59	-3	118	110	-8
6	78	69	-9	144	124	-20
8	77	78	1	143	139	-4
10	88	86	-2	154	152	-2
12	95	94	-1	172	165	-7
14	95	102	7	171	178	7
16	98	109	11	174	190	16
18	105	119	14	185	202	17
20	137	121	-16	229	214	-15
22	133	126	-7	225	225	0
24	133	131	-2	234	235	1
26	133	135	2	246	245	-1
28	133	139	6	246	255	9
30	143	142	-1	274	264	-10

CONCLUSION

A unique mathematical equation was generated for each of the four farm sizes of 5, 10, 15 and 30 sows. In all the cases the equation was a second order polynomial equation, except in the case of the 10 sow farm where the equation was linear. However, even in the case of the 10 sow unit farm, the second order polynomial equation had the same coefficient of determination R^2 as the linear equation, but the linear equation was chosen because it was simpler. For all the farm sizes the R^2 was at least 80 %, which means that the equation can explain at least 80 % of the variation. All models had capacity of predicting the exact number of pigs on the farm. This implies that the developed models can assist small scale farmers with up to 30 sows in projections of their production operations in terms of how may pigs to expect from their breeding stock.

RECOMMENDATIONS

It is desirable to do a further study of this kind for a long duration with enough time to cover the entire reproductive period of the sows so that the pig numbers can reach a maximum threshold for each farm size. Future studies should also incorporate aspects of modeling gross margin analysis to determine the herd size which would be profitable.

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Conflict of interest: None

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