On-farm research leading to a dynamic model of a traditional chicken production system

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Abstract
A series of on-farm and on-station experiments on management and production of local chickens were conducted in Zimbabwe between 1998 and 2001. The overall aim of studies was to improve smallholder farmers' livelihood and empower women through production of local scavenging chickens. Knowledge exists that poultry can be used as a tool for poverty alleviation and strengthening of women's status. The combination of on-farm and on-station experiments complemented each other well and increased understanding of the complex factors influencing traditional chicken production. Farmers' participation was a main focus throughout the on-farm studies and experiments were designed to rely heavily on farmers' own data collection. The experiences were positive although missing data were a continuous problem throughout. Initially, the traditional chicken production in a study area in Zimbabwe was described and constraints and opportunities for production investigated. Thereafter an on-station experiment established that the production potential of the local chickens both for eggs and meat were higher than expressed under on-farm conditions. On the basis of these two trials, a third experiment was planned on-farm while using the obtained experiences. Possible improvement through crossbreeding was investigated in a fourth trial on station. The tested interventions did not lead to expected improvements of production. Merely results showed a tremendous variation in production between farms and this variation tended to overrule the effect of interventions. However, the findings suggest that there are room for improvements and that some farmers have extended knowledge about production. As a supplement to time-consuming and labour intensive on-farm experiments and as a tool to systematically describe the production system, a dynamic model of a traditional African chicken production system was developed. The model: SimFlock can through simulations establish correlations between selected outputs (e.g. maximum number or kg of chickens produced, number of eggs produced and net return of the production) and production parameters (e.g. growth and survival). Thus it can provide answers to which parameters are of most importance in relation to outputs. SimFlock provides a holistic description of the production system and the outputs produced reflect the random variation within flocks as well as between flocks. This is important for representation of the risk of production. SimFlock might be used as a management and extension tool. The continuous interaction between researcher, farmer, on-farm experiments, on-station experiments and a systematic description led to an understanding of the system in a model, which is based on common values by the farmer and researcher. This is essential since common understanding aid improvements.

Introduction
Chicken production in most African countries is traditionally based on scavenging systems. Approximately 80% of chicken populations in Africa are reared in these systems (Guéye, 1998). This low input/output practice has been a component of smallholder farms for centuries and will probably continue to be so in the future. There are many advantages in this production system but also constraints. The advantages consist of a production based on free

feed resources available in the surrounding environment and kitchen leftovers, using local chicken breeds, which has adapted to the conditions, and preserved their ability to incubate and brood naturally. All these factors maintain an inexpensive and low management level production. The constraints are high mortalities, low egg production and slow growth. Thus in recent years more focus has been on how the constraints can be minimised and thereby increase the overall production. A variety of factors act over time to influence productivity and thus dynamic management tools are useful. A dynamic stochastic model: “SimFlock” of the traditional African chicken production system has been developed as a supplement to on-farm and on-station trials.

The objective of developing a dynamic and stochastic model of a traditional chicken production system is to test, theoretically, the effect of different interventions on chickens’ performance by simulating the transition of birds between various stages of the production cycle when taking several operations into account. This is done at flock level but the individual bird is an important feature. Given a number of available resources, constraints and interaction by the farmer, the model is able to generate an output in terms of e.g. sold and slaughtered chickens, egg production and net return of production. The model can also answer what the outputs are if changes occur in the system and as such be used as an extension tool. Further, SimFlock can establish correlations between outputs and given production parameters.

The aim of the experiments was to improve traditional chicken production by increasing survival and growth. Experiences from Bangladesh showed that farmers’ livelihood and women empowerment were increased through improved chicken production (Alam, 1997; Danida, 1998). Further, it is a well known fact that most of the income, controlled by women in developing countries, is spent directly on sustaining and improving the livelihood of the families (Miller, 2001). Moreover, due to the low investment costs in chickens, it is an enterprise that even the poorest farmers are capable of venturing into.

Methods and materials

After farmers had identified a need for research on chicken production (Muchenje and Sibanda, 1997), a series of on-farm and on-station experiments were conducted in Zimbabwe between November 1998 and May 2001. On-farm experiments were conducted in Sanyati communal farming area 250 km Northwest of the capital Harare. On-station experiments were conducted at Henderson Research Station in Mazoe.

Initially an on-farm study was conducted to describe the existing chicken production system and characterise the chickens. Constraints and opportunities for improvements in the production were identified and the survey was used to plan further research. Since very little was known about the production potential of the local chickens in Zimbabwe it was decided to carry out an on-station experiment to establish the growth potential as well as the egg production potential of local chickens under improved conditions. The on-station experiment showed that chickens’ production potential for both meat and eggs was much higher than what is usually found on-farm. Another on-farm trial was thus planned with the purpose of improving the traditional chicken production in such a way that the number of chickens ready for slaughter and sale was increased. Housing of chicks (0-3 weeks), feed supplementation and anthelmintica were all thought to have a positive effect on growth rate and survival of chickens. No emphasis was put on egg production since farmers’ priority was meat production. Farmers were responsible for record keeping and Field Technicians visited farms once a week to help farmers fill in missing records and weigh chickens. In the same time as the second on-farm trial was running another on-station experiment was conducted to establish the growth potential of crossbred chickens (Cobb #500 parents x local), since crossbred chickens in Bangladesh had proven to produce better than exotic breeds and local breeds under scavenging conditions (Barua *et al*., 1998; Haque *et al*., 1999).

Based on knowledge obtained and data collected in these four experiments an object-oriented dynamic stochastic model *SimFlock* was developed. Such a model can serve as a supplement to time-consuming and labour intensive on-farm experiments. The objective of the model was to predict the effect of different interventions on selected outputs and to establish correlations between outputs and production parameters. Figure 1 illustrates the series of on-farm and on-station experiments leading to a dynamic model.

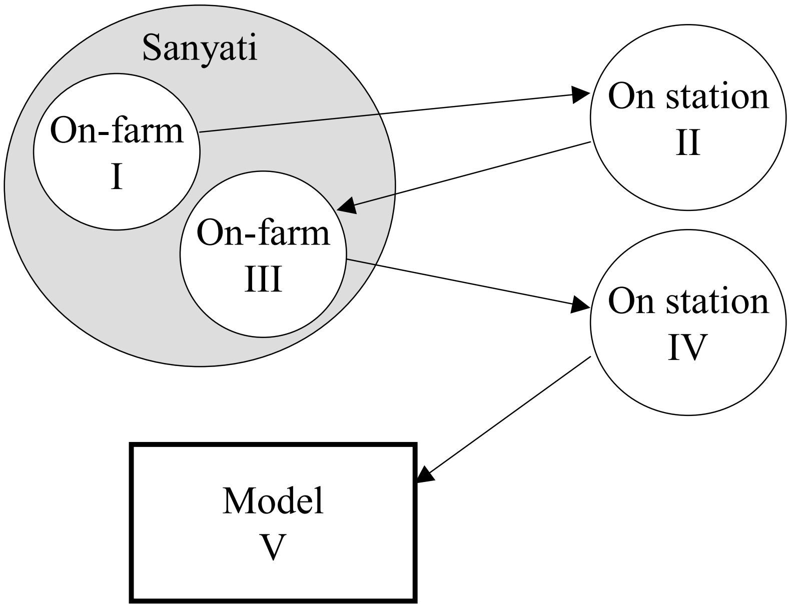

Figure 1: Experiments leading to a dynamic model

The biological parameters used as input data in SimFlock were obtained from the on-farm studies. These parameters can be altered according to area-specific parameters. The standard flock used as a basis for the model was a flock of 5 hens and 1 cock producing chickens from hatch to finish in a scavenging system, representing a traditional chicken production system in rural Zimbabwe, where people keep chickens mainly for meat production. As a consequence of high mortality and slow growth, the vast majority of eggs are needed for incubation in order to sustain flock numbers. This scenario is common throughout rural Africa (Guéye, 1998).

The user interface is described at http://www.prodstyr.ihh.kvl.dk/software/simflock/, where the SimFlock software can be downloaded from. It comes as one single jar-file, which can be saved to the hard disk by following instructions.

Three simulation jobs were selected to demonstrate the use of the model. The number of farms selected was 100 with 50 replications per farm in a simulation period of 3 years. The simulation jobs run were:

1. Default settings only.
2. Egg collection for 20 days of each laying period. Surplus eggs were sold.
3. Growth rate increased by 100%.

The changes made in the second and third simulation was based on results from on-farm and on-station experiments. Here it was found that by collecting eggs for home consumption or sale, egg production could be doubled. Further, it was shown that growth of chickens could be improved considerably by raising them under improved conditions.

Results

From the first experiment (on-farm), it was concluded that the most visible constraints to local chicken production were high mortality and slow growth caused by diseases, predators, inadequate management as well as limited and varying feed supplies. Findings confirmed that women owned most chicken flocks and that income generated from chicken production was spent in direct relation to nutrition, health and education of the family. The second experiment (on-station) showed that chickens under improved conditions could perform better than what was found on-farm. Meat and egg production as well as survival was considerably higher. Thus, their genetic potential was higher than usually considered. In general the improvement, which was thought introduced through the third experiment (on-farm) with feed supplementation and housing, was not visible. Production was not increased. For all production parameters there was a substantial variation between farms. In figure 2 the variation in chicken survival between farms is shown. The fourth experiment (on-station) with crossbred chickens showed a considerable improvement in growth.

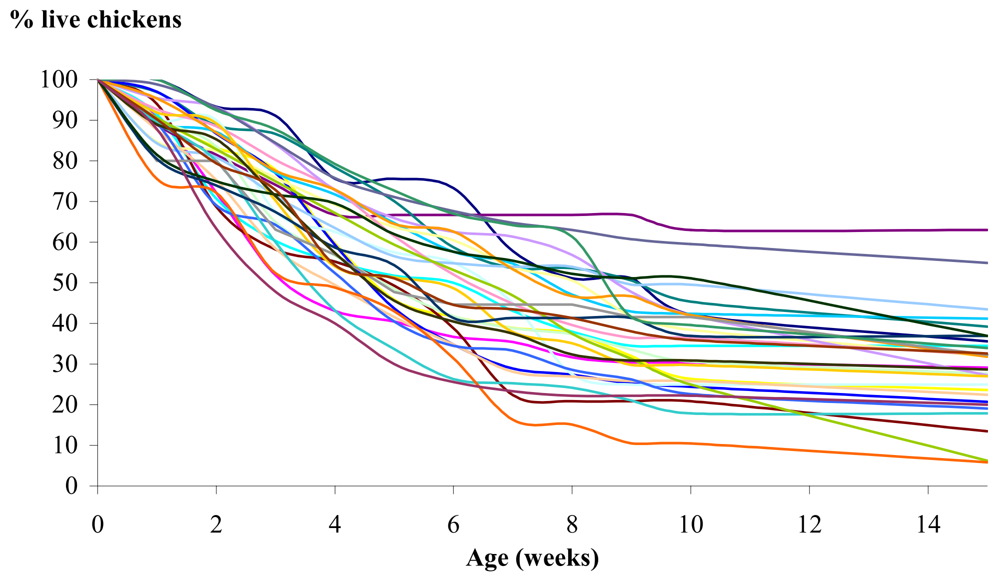

Figure 2: Survival of chickens found on-farm. Illustrates the high variation between farms.

Output obtained from a simulation included number of chickens consumed and sold, number of eggs laid and sold, kg of meat sold and consumed, number of feeding days for all age groups, average daily gain as well as total weight gain for all age groups, number of hens and cocks bought, total costs, total income and total net returns. Table 1 summarises some outputs in question for each of the three defined simulations.

Table 1: Outputs for each simulation of 100 states of nature (farms) with 50 replications over 3 years. Figures in parentheses are standard deviations.

Output	Simulation 1 Default	Simulation 2 Egg collection	Simulation 3 Increased growth
Number of chickens produced	45 (1.1)	38 (1.0)	43 (1.1)
Total weight of chickens produced (kg)	54 (1.3)	47 (1.2)	83 (2.0)
Egg production	488 (4.4)	1100 (9.5)	485 (4.5)
Net return (US$)	-50 (1.8)	20 (2.0)	-30 (2.8)

A forward stepwise regression analysis was done for each output in question. An example is shown in table 2. The parameters with the largest effect on outputs are listed. A plot of the output against the parameters of highest influence illustrates their correlations. An example is shown in figure 3, which clearly shows the positive correlation between chicken survival and number of chickens produced.

Table 2: Results from a stepwise regression analysis, showing the influence (R-square) of the most important parameters on total number of chickens produced as average of simulation 1 – 3.

Biological parameter	Partial R-square	Model R-square
Grower survival	0.29	0.29
Pullet/Cockerel survival	0.16	0.45
Chick survival	0.07	0.52
No. of incubated eggs	0.06	0.58
Egg hatchability	0.05	0.63

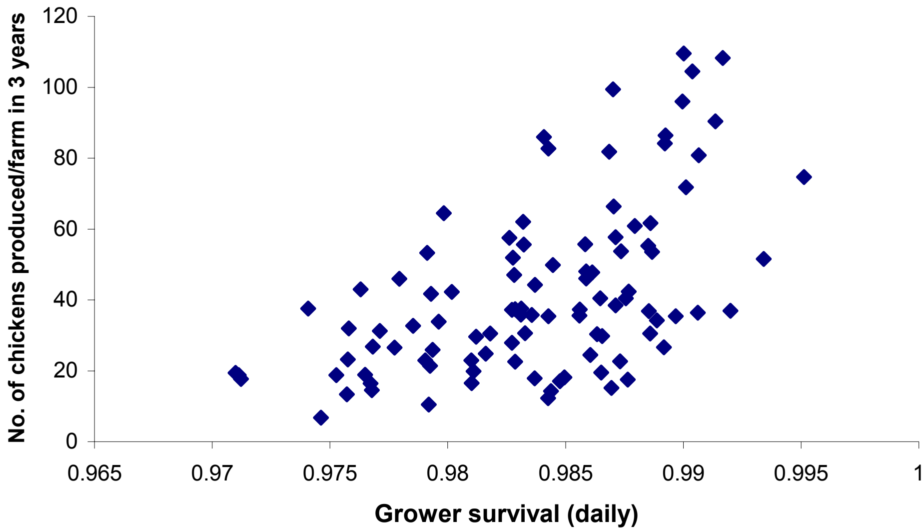

Figure 3: Correlation between total number of produced chickens and grower survival

For total weight of chickens produced the stepwise regression analysis showed that the production parameters of highest importance again was chicken survival. In addition, slaughter age was of major importance. The stepwise analysis for egg production showed it was mainly influenced by no. of eggs incubated per clutch and chicken survival. Finally net return was influenced by hen survival followed by selling age of chickens and chicken survival.

For each output, simulations could illustrate the variation between and within farms, based on on-farm studies. In figure 4 this variation is shown for number of chickens produced in simulation 1. For comparison, mean values and variations between and within farms found on-farm for a number of important production parameters are shown in table 3. These values were used as input parameters to SimFlock.

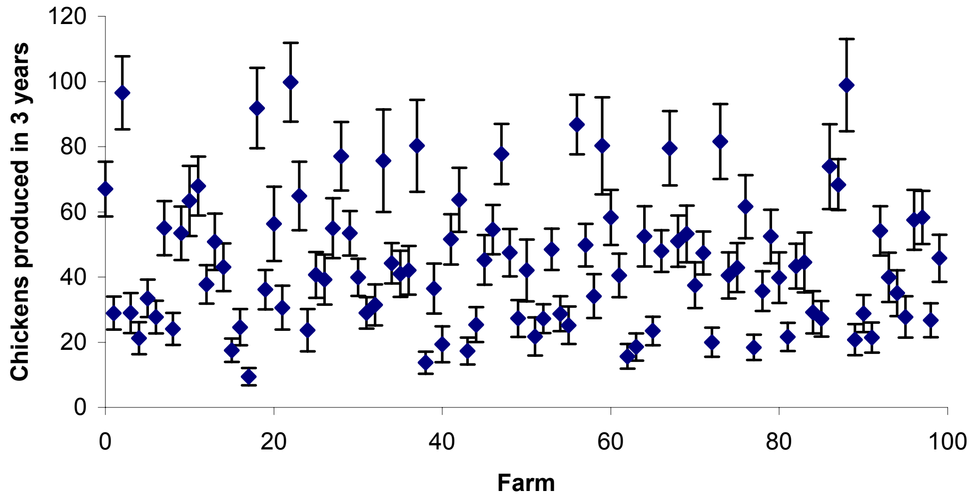

Figure 4: Variation in number of chickens produced within and between farms

Table 3: Mean value and standard deviation shown for some important production parameters.

Production parameter	Mean value	Std. dev. between farms	Std.dev. within farms
Number of eggs incubated/clutch	10.1	1.2	2.9
Egg hatching probability	0.71	0.04	0.27
Growth rate of chicks, 0-3 weeks (g/day)	2.2	0.4	1.1
Growth rate of growers, 3-10 weeks (g/day)	6.6	1.2	2.3
Survival of chicks, 0-3 weeks (in total)	0.69	0.11	-
Survival of growers 3-10 weeks (in total)	0.46	0.14	-

Discussion

Results of on-farm experiments showed a high variation within and between farms. Since this data was used as input for the simulation model, results of simulations showed the same picture. However, simulations produced data on a larger scale since multiple replications could be run for more farms. When simulation results were analysed further through a

stepwise regression analysis, the production parameter with most influence on the output in question could be identified.
Fewer chickens were produced in simulation 2 compared to simulation 1 and 3. This was caused by longer laying periods (almost 20% longer) and thus fewer clutches per year. Similarly, the total weight of chickens produced was lowest in simulation 2. Total weight of chickens produced was highest in simulation 3 due to increased growth rate. It is seen from table 1 that the amount of produced meat in simulation 3 is between 1½ and 2 times higher compared to simulation 1 and 2. If eggs were collected for 20 days in each laying period, egg production increased from approximately 485 to 1100 in the 3 years' simulation. This was equivalent to approximately 41 extra eggs/hen/year, which was more than double the production in the default situation. However, it was not unrealistic since it was shown in the first on-station trial that local hens could lay 96 eggs/year. Further, the second on-farm trial had shown that one farmer practiced egg collection successfully and hereby increased egg production by 65%. As a consequence of increased egg sales, average net return increased too. Sold chickens and eggs represented the only cash income gained from the production. Net return was thus highly positively correlated with number of sold chickens and negatively correlated with number of consumed chickens, since no value was set for chickens consumed. The increase in net return in simulation 3 compared to simulation 1 was due to the increased weight of sold chickens. Thus they obtained a higher price. Consumed chickens also weighed more and thus home consumption in simulation 3 was higher than in simulation 1. If instead home consumption was kept at the same level and all extra meat were sold, net return would have increased more, since the price of chickens sold was per kg live weight.

Total number of chickens produced was positively correlated with survival of chickens, number of incubated eggs and hatchability of eggs. It is easily explained since higher survival resulted in more live chickens ready for slaughter and sale and more incubated and hatched eggs resulted in more live chickens (as long as survival was unchanged). Total weight of chickens produced showed a similar correlation with these production parameters and in addition it was also positively correlated with slaughter weight. Egg production was positively correlated with number of eggs incubated per clutch since more eggs per clutch resulted in a higher total egg production. This correlation was less pronounced when egg collection occurred since no. of eggs incubated per clutch did not include the collected eggs. These extra eggs were sold. Further, egg production was negatively correlated with chicken survival since the hen started laying again if all chickens in a clutch died. Thus clutch interval would be shortened and egg production would increase. Hen survival was positively correlated with net return because SimFlock replaced dead hens, if necessary by buying in new hens.

Results showed a clear positive correlation between level of production and the variation in production (figure 4). Hence the higher production level a farm had the higher variation occurred in this production, which is not surprising.

SimFlock was developed on the basis of results from on-farm experiments and results from on-station trials were used to create realistic simulation scenarios. The understanding of the system in a model, based on common values by the farmer and researcher, was only possible due to continuous interaction between researcher, farmer, on-farm experiments, on-station experiments and a systematic description of the production system.

Conclusion

SimFlock can through simulations establish correlations between outputs and production parameters under on-farm conditions. SimFlock can provide answers to which parameters, e.g. growth and survival, are of most importance in relation to selected outputs like number or weight of chickens produced, egg production and net return of the production. SimFlock provides a holistic description of the production system and the outputs produced reflect the random variation within flocks as well as between flocks. This is important for representation of the risk of production. Hence, simulations can provide answers to what the expected changes in output will be if specific production parameters are changed. SimFlock has the potential to be used as a management and extension tool.

An understanding of a production system based on common values by the farmer and researcher is essential if research should lead to improvements in production. The complexity of production will then have been accounted for, interventions will be practical and labour time will be in relation to benefits. Further, farmers will be positive towards cooperation with researchers.

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