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A FORWARD AND BACKWARD LINKAGE AGRICULTURAL PRODUCTION SIMULATION MODEL

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ABSTRACT

This paper illustrates the use of a forward and backward linkage agricultural production simulation model. CHICKSIM III is a comprehensive, farm-level, and stochastic capital budgeting simulation model which provides an analytical framework for simulating probable consequences of production, marketing, financial, and policy variables on the profitability of a farm or agribusiness firm. The model is applied to evaluate the profitability of a representative farm producing broiler, beef, corn, and kenaf.

1 INTRODUCTION

The use of farm-level simulation models has a long history in agricultural application (Klein and Narayanan 1992). For example, various single-product simulation models have been formulated to estimate yields for specific crops. Examples are the SORGF model for sorghum (Maas and Arkin 1978), TAMW model for winter wheat (Maas and Arkin 1980), CORNF model for corn (Stapper and Arkin 1980), and the COTTAM model for cotton (Jackson, Arkin, and Hearn 1988). Multiple-product models have also been developed that combine two or more techniques to represent an integrated farm operation. Dillon, Mjelde, and McCarl (1989) generated yield estimates using the SORGF, TAMW, CORNF, and COTTAM models and integrated these with an economic model using quadratic programming to study the economic feasibility of Texas Blacklands corn production in relation to sorghum, wheat, and cotton. Bosch and Eidman (1987) used simulation and general stochastic dominance to value information when risk levels are neutral for a representative southwest Minnesota farm producing irrigated (corn and soybeans) and unirrigated crops (corn, soybeans, and rye).

For aquaculture production, AQUASIM was used by Gempesaw and Bacon (1993) to evaluate the risks and returns associated with specialization and diversification in the production of broilers, hybrid striped bass, and catfish in the Mid-Atlantic region. While this model is capable of simulating an integrated aquaculture operation and can represent transfers of output from one production stage to another, it can only model the forward linkages in the production system. AQUASIM allows the outputs from an earlier stage to be used as inputs for a later stage but cannot simulate the flow of inputs from a later stage to an earlier stage. In an integrated farm with crops, poultry, and livestock, it is possible to use crops as inputs into poultry and livestock production (e.g., corn as feeds) and at the same time use by-products from poultry and livestock production as inputs to crop production (e.g., manure as fertilizer). The cyclical process requires the use of a model which can simulate not only forward linkages in the system but also backward linkages.

The main objective of this paper is to develop a model (CHICKSIM III) which can simulate the operations of an integrated farm including the forward and backward linkages between various production processes. The second objective is to simulate the operations of integrated and specialized representative Delaware farms producing broiler, beef, corn, and kenaf using CHICKSIM III. Data sets reflecting the different combinations of inputs and outputs will be created to compare the profitability of specialized and integrated farms and to evaluate the use of alternative sources of inputs. Lastly, this paper will discuss the results of the various scenarios simulated for the representative Delaware farms.

2 SIMULATION MODEL

CHICKSIM III, the updated version of AQUASIM, is a comprehensive, farm-level, and stochastic capital budgeting computer simulation model. Written in FORTRAN and using the accounting subroutines from FLIPSIM V (Richardson and Nixon 1986), this model includes additional subroutines to model the production and financial performance of multiple output, multiple input and vertically or horizontally integrated farms and agribusiness firms. Recently, additional improvements were made in the model to include the use of biophysical variables in production estimation and the simulation of cyclical and backward flows of inputs between stages in the production process. The enhanced flexibility of the model allows the analyst to:

1. Model multi-output, multi-input enterprises (e.g., joint production of broiler, kenaf, beef, and corn).
2. Model the simulation of enterprises that produce products (outputs) that are used as factors (inputs) in the next stage of operation (e.g., a broiler farm that is producing manure that can be used as fertilizer or feed ingredient in another stage; a total of 10 stages-outputs is allowed with the current memory dimensions; the upper limit on the number of stages-outputs is determined by the available computer memory).
3. Simulate production processes with different time periods (e.g., weeks, time period=52; months, time period=12; a total of 120 time units is currently available; the upper limit is again determined by the computer memory). The different stages are not required to have similar production time periods (e.g., chickens require 2 months per flock with continuous stocking after harvest while corn, kenaf, and beef production may need 6 months with only one stocking at different periods of time during the year).
4. Specify stochastically most control variables (output quantities and prices, variable input costs, mortality and feed conversion rates, etc.) using several optional probability distributions (triangular, beta, normal and lognormal) within each production stage. The model can simulate a poultry farm producing broilers following a lognormal distribution and aquaculture following a triangular distribution.
5. Select output and price relationships such that a random high output quantity will be correlated with a low random output price and vice versa.
6. Estimate variable costs of production using pre, average, or post mortality population.
7. Control variable cost specification on a per unit (per head) or weight basis and monthly allocation of variable cost. For example, harvesting costs will only be incurred during the last two months of an eleven month production cycle.
8. Model production with a quota option along with penalties for exceeding the quota based on price reduction or addition of the penalty cost to total production cost.
9. Impose a loan deferral payment scheme for cash flow purposes during the initial life of the project.
10. Sell excess outputs not needed in the next stage or buy deficit inputs required in the next stage.
11. Use biophysical variables such as rainfall, temperature, fertilizer type, farming methods, and others in production estimation.
12. Model cyclical and backward flows of inputs in addition to forward and one-way flows of inputs between stages.

The backward and forward linkages of a system represent the transfer of inputs and outputs between the different production processes and also the selling of the final products. The model simulates these linkages through matrices showing the transfer rates, conversion ratios, and sales percentages. The transfer rate specifies how much of the output from one production process will be transferred as input to another stage. The conversion ratio computes the equivalent quantity of that input in the receiving production stage. For example in a system which produces corn and livestock, the transfer rate matrix can specify that 50 percent of the corn output is used as feed inputs for livestock production. The conversion rate specifies how many tons or bushels of corn feed is needed to produce a unit of livestock output measured either in terms of weight or number of heads. The sales percentage reflects how much of the output is sold in the outside market.

Transfers from one stage to another may mean the actual transfer of an output or the transfer of a by-product from one stage to another. However, there is a difference between the transfer of an output from the mere transfer of a by-product and this is reflected in the options given by the model for the transfer and sales matrices. The default option is for the transfer of the output itself where sales occur before the transfer. The sales percentage is based on the total production while the transfer percentage is based on the remaining quantity after the sales. For instance, if stage 1 has 100 units of output with 50 percent sales and 100 percent transfer, it means that 50 units will be sold (50 percent of the total production of 100 units) while 50 units will be transferred to another stage (100 percent of the remaining quantity after sales). For stages where there is a by-product, the transfer precedes the sales. Since the transfer of the by-product does not actually reduce the output, the quantity transferred is not subtracted from the output. It is then possible to have 100 percent transfer of the by-product and 100 percent sales of the final output. An example would be the broiler production which generates broiler meat and the manure as by-product. The broiler meat can be sold 100 percent and 100 percent of the manure can also be transferred for use as feed or fertilizer in another stage. In cases where the output is not sold but rather transferred from stage 1 to stage 2 while the by-product is also moved to a separate stage (3), a dummy stage can be created. The output will be "sold" to the dummy stage which will transfer that output to the receiving stage (2).

Figures 1 and 2 illustrate the forward and backward linkages. An integrated farm system such as a fish production system may have only forward linkages (Figure 1). From the fingerlings to the market-size fish, the production process moves forward without any backward flows. Figure 1 reflects the flow of inputs in a system with purely forward linkages.

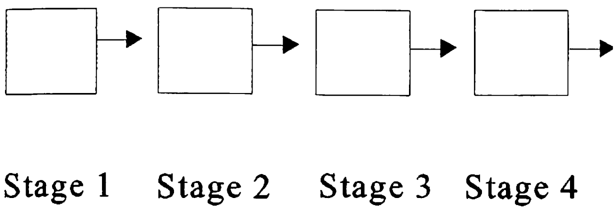

Figure 1: Integrated Farm System with Forward Linkages

However, some integrated farms system are more complex since the outputs from one production process can be used as an input to another production process. Figure 2 reflects an integrated farm with three production stages where stages 1 and 2 provide inputs for stage 3 which in turn provides inputs for stage 1. The flow of inputs from stage 3 to stage 1 reflects the backward flow of the inputs.

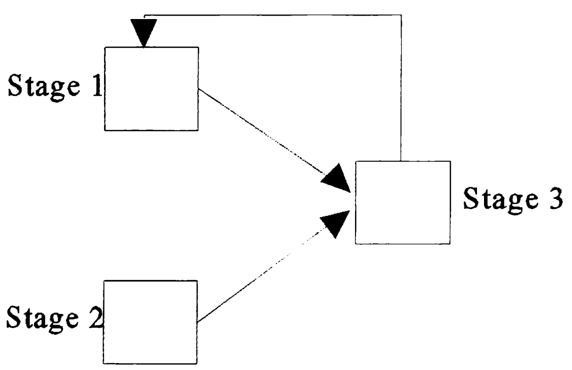

Figure 2: Integrated Farm System with Forward Backward Linkages

3 MODEL APPLICATION

The model, CHICKSIM III, is applied to simulate the operations of specialized and integrated representative Delaware farms producing broiler, beef, corn, and kenaf. The farms were simulated iteratively with the results forecasted for a period of ten years. The specialized farms are the broiler farm, beef farm, and corn farm. Kenaf is being promoted for the use of its core as bedding material for broiler production instead of the more commonly used material, pine sawdust. Therefore, kenaf is grown only with broiler production and is not considered as a specialized product. The main output of the representative Delaware farm is broiler meat which is assumed to be produced in all integrated farms. The integrated farms are the broiler-beef farm, broiler-corn farm, and broiler-beef-corn farm. Figure 3 shows the production characteristics of each output.

The fully integrated farm produces all four outputs. The final outputs are broiler, beef, corn, and kenaf fiber. Kenaf core is an intermediate output which is used as bedding material for broiler production. Broiler litter (bedding plus manure), a by-product, is used as fertilizer for corn and kenaf production and as feed rationing ingredient for beef production. Figure 4 shows the relationship of inputs and outputs between the different production stages. With the use of CHICKSIM III the transfer of the by-products kenaf core and broiler litter can be modeled.

Data sets were created for the different scenarios to compare the profitability of specialized and integrated farms and to evaluate the use of alternative sources of inputs. The current practice is for the broiler integrator company to supply the sawdust to growers. Therefore, as far as the grower is concerned, the bedding material is free. In order to compare the use of kenaf core and sawdust as bedding materials, it is necessary to include its cost in the broiler production. The use of the conventional bedding material, pine sawdust, was compared to the alternative material, kenaf core. The different sources of kenaf core were also considered since it is possible for the farm to buy from outside sources or to grow kenaf within the farm. Producing kenaf requires the separation of the raw material into kenaf fiber and kenaf core which is performed as a custom operation along with harvesting. This leads to two more options where the farm may choose to pay for the custom operations and sell the fiber or trade it in exchange for the custom operations. In addition, the viability of broiler litter as fertilizer and feed rationing ingredient was evaluated and compared to the use of conventional fertilizers and feed ingredients. A total of 55 scenarios was generated and simulated using CHICKSIM III.

4 RESULTS

The major results based on the simulation of the various scenarios are presented as follows. Table 1 shows the financial indicators for the specialized and integrated farms. Among the specialized farms, only the broiler farm has a positive net present value (NPV). The beef and corn farms both have internal rates of return (IRR) below the cut-off point of 5 percent. On the other hand, all the integrated farms show positive NPVs which are higher than that of the specialized broiler farm. The same is true for the IRR. This would imply that while beef and corn production in a representative Delaware farm may not be profitable ventures as independent farm enterprises, it can be made profitable when integrated with broiler production.

Table 2 compares the different scenarios for specialized broiler farms and the different sources of bedding materials.

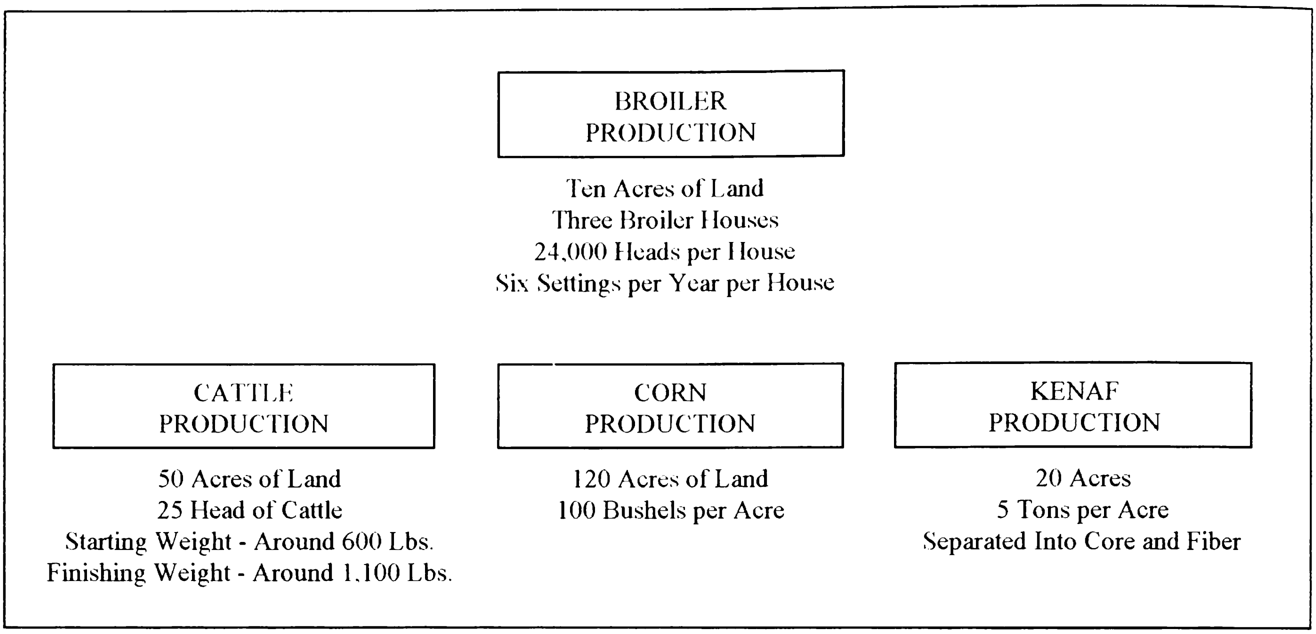

Figure 3: Production Characteristics of a Representative Delaware Farm

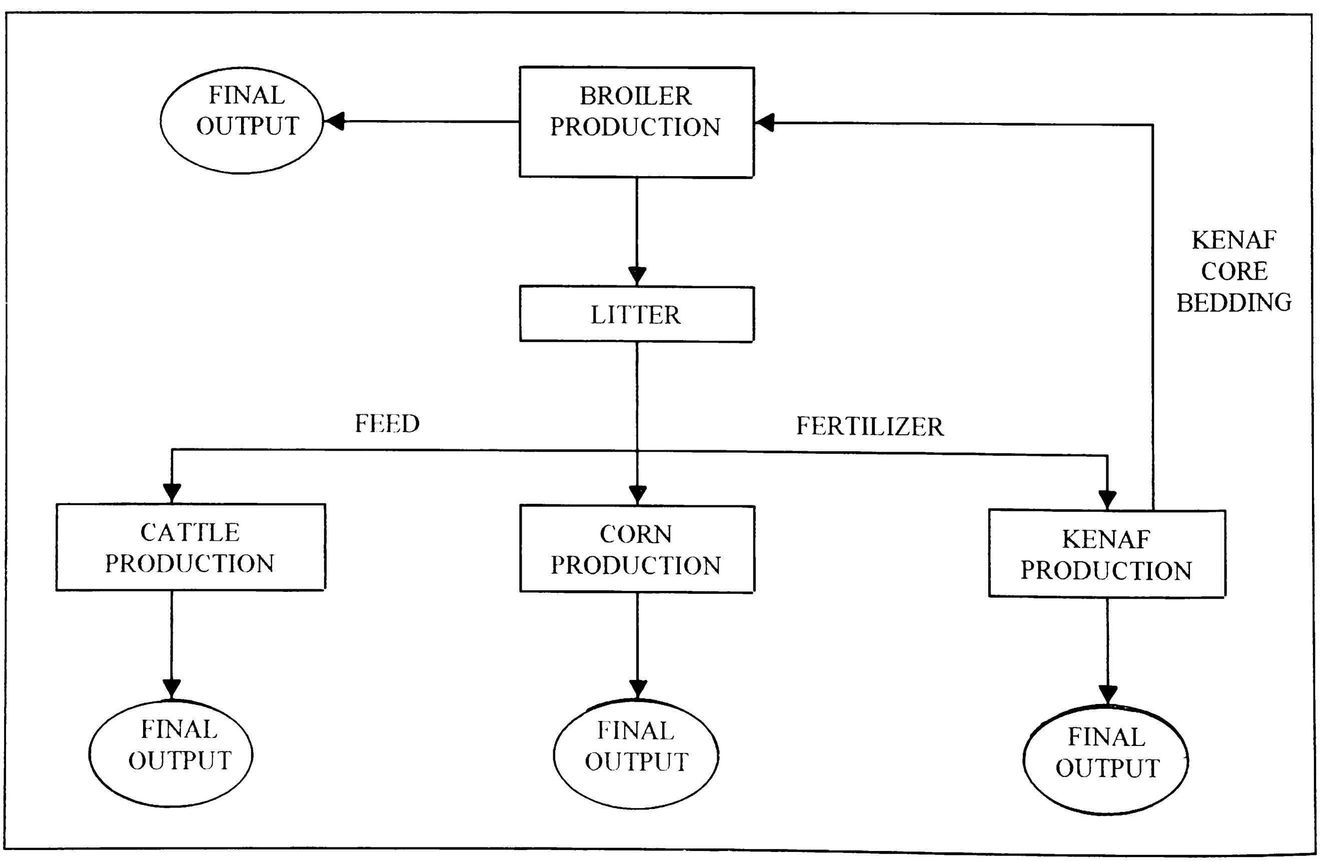

Figure 4: Integrated Farm Model for a Representative Delaware Farm

If the grower has to buy sawdust for the broiler farm, the NPV of the farm would decrease by $40,521.60. On the other hand, if the grower buys kenaf core material, the difference in NPV is only $28,554.40. In terms of IRR, the purchase of sawdust leads to a decrease of almost one percentage point while the purchase of kenaf core leads to only a three-fourths of a percentage point decrease. While the grower does not really have to concern himself about the price of sawdust and the fact that kenaf is a cheaper alternative source of broiler bedding material, this information may be useful for poultry integrators who are supplying the bedding material.

Based on the simulation results, buying kenaf is more profitable than growing kenaf in a specialized broiler farm. If the farm grows kenaf and trades the fiber for the custom services, the decrease in NPV is $17,023.91. However, if the farm grows kenaf and sells the fiber, the decrease in NPV is only $13,331.80. If the farm grows kenaf and uses the broiler litter as fertilizer for kenaf, the NPV increases by more than $3,600.00. This is true for both cases when the kenaf fiber is traded and when it is sold.

While it is not profitable to grow kenaf on a broiler farm and a broiler-beef farm, the results show that it is better to grow kenaf on a broiler-corn farm. This is true since the production of corn and kenaf can share in some common planting equipment and machinery. Table 3 shows the financial indicators for the broiler-beef-corn farm scenarios. These scenarios show the effect of using broiler litter on the performance of the integrated farm. Using the broiler litter as fertilizer for corn and kenaf increased the NPV by at least $19,295.60 (under the "free sawdust" scenario) and at most $19,770.60 (under the "buy sawdust" scenario). The increase in the IRR is almost one third of a percentage point.

Table 1: Ten-Year Projected Average Annual Financial Indicators for Specialized and Integrated Representative Delaware Farms

Scenario	NPV ($)	IRR (%)
BROILER FARM	142,196.40	8.91
BEEF FARM	- 6,822.07	2.09
CORN FARM	- 36,340.70	2.74
BROILER-BEEF	150,418.70	8.93
BROILER-CORN	171,098.60	7.71
BROILER-BEEF-CORN	166,662.50	7.50

Table 2: Ten-Year Projected Average Annual Financial Indicators for Specialized Representative Broiler Farms in Delaware Using Various Broiler Litter Materials

Scenario	NPV ($)	IRR (%)
FREE SAWDUST	142,196.40	8.91
BUY SAWDUST	101,674.80	7.85
BUY KENAF CORE	113,642.00	8.17
GROW KENAF		
1. trade kenaf fiber for services	96,618.09	7.21
2. sell kenaf fiber	113,079.20	7.64
3. trade kenaf fiber and use litter as fertilizer	100,310.20	7.31
4. sell kenaf fiber and use litter as fertilizer	116,740.80	7.72

Table 3: Ten-Year Projected Average Annual Financial Indicators for Specialized Representative Broiler-Beef-Corn Farms in Delaware

Scenario	NPV ($)	IRR (%)
FREE SAWDUST		
1. Use conventional feeds and fertilizer	166,662.50	7.50
2. Use litter as fertilizer	185,958.10	7.79
3. Use litter as feed ingredient	180,328.40	7.71
4. Use litter as fertilizer and feed ingredient	199,422.50	7.99
BUY SAWDUST		
1. Use conventional feeds and fertilizer	126,604.50	6.85
2. Use litter as fertilizer	146,375.10	7.17
3. Use litter as feed ingredient	140,516.50	7.08
4. Use litter as fertilizer and feed ingredient	160,156.70	7.39
BUY KENAF CORE		
1. Use conventional feeds and fertilizer	138,382.70	7.04
2. Use litter as fertilizer	158,037.30	7.35
3. Use litter as feed ingredient	153,824.90	7.29
4. Use litter as fertilizer and feed ingredient	173,242.70	7.60

The effect of using broiler litter as feed ingredient varies depending on the type of bedding material used. The use of sawdust-based feed led to an increase in NPV of more than $13,000.00. On the other hand, the use of kenaf-based feed increased the NPV by over $15,000.00. The increase in IRR is slightly higher for the case when kenaf-based feed is used instead of the sawdust-based feed. Lastly, the effect of using the litter both as fertilizer and feed ingredient was simulated. The increase in the NPV ranged from $32,700.00 to $34,860.00, while the IRR increased by approximately one-half percentage point.

5 SUMMARY AND CONCLUSIONS

CHICKSIM III was developed to simulate the operations of an integrated farm enterprise. Various options were incorporated in the simulation model to allow for the interaction of the different inputs and outputs within the farm. The simulation model can represent backward linkages and cyclical processes in an integrated production operation. The model can also compare different scenarios reflecting different production structures (specialized and integrated), broiler bedding materials (pine sawdust and kenaf core), fertilizer and feed ingredients (litter-based and conventional).

This study has compared the performance of specialized farms versus integrated farms with special emphasis on broiler farms. In the analysis of specialized and integrated farms, this study included the production of beef and corn in addition to broiler meat. Furthermore, it has considered the use of alternative materials for bedding, feeds, and fertilizer. More specifically, the use of kenaf as bedding material and the use of broiler litter as feed ingredient and fertilizer were investigated.

The simulation results for the representative farms show that broiler production is the only viable project in a specialized farm. However, integrating corn and/or beef production with broiler production can increase the profitability of the enterprise. Kenaf core has proven to be a more profitable alternative as broiler bedding material compared to pine sawdust. If grown with corn, kenaf production can be recommended. However, for farms producing only broiler and/or beef, it is better to buy kenaf core from other sources. The use of litter-based fertilizer and feeds can decrease input costs and increase the profitability of the integrated farms.

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