A STRATEGIC PLANNING MODEL FOR AGRICULTURAL PRODUCTION

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The increasing importance of the operations/production function in the strategic planning process poses new demands for decision support tools tailored to address strategic issues. Decision support systems are generally geared to short-term tactical and operational decision making. As an alternative, this paper focuses on developing decision support tools for use in strategic planning. Specifically, we develop a mathematical programming model to evaluate long-term strategic alternatives in the context of farm-level agricultural production where a broiler farm considers the long-term implications of diversification into commercial aquaculture. The model considers a

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ten-year strategic planning horizon, incorporates financial risk considerations, and accommodates capacity variations. Results indicate that a diversification strategy will significantly increase farm profitability over a strategic planning horizon while simultaneously maintaining financial risk associated with diversification below a predetermined maximum tolerance level.

INTRODUCTION

Organizations, facing the uncertain nature of the business environment, have implemented strategic management as a primary means of survival. Traditionally a task only for top management, changed circumstances have motivated the inclusion of numerous functional areas within the organization into the strategic planning process. Specifically, the changing operating environment is forcing a new relationship between strategic planning and the operations/production (O/P) function. O/P requirements are now being considered as major priorities with respect to strategic planning, as opposed to the strategic planning process forcing constraints on the O/P function (Helms, 1989; Adam & Swamidass, 1989).

The changing role of the O/P function in the strategic planning process poses new demands for decision support tools tailored to address strategic issues. The diffusion of strategic planning in the O/P function requires availability of decision models covering longer time spans and versatility of decision models to reflect the unique features of long-term decisions. In a review of operations management literature and operations strategy, Adam and Swamidass (1989) made two points: researchers have ignored the importance of operations management to strategic planning and theory building in operations strategy is seemingly stalled by a lack of quality empirical research.

Huchzermeier (1991) and Huchzermeier and Cohen (1992a, 1992b) have developed globalized manufacturing strategy planning models, from the perspective of supply chain network design, to analyze financial and operational hedging strategies. Their models explicitly considered costs of supply chain network options, costs of alternative product designs and stochastic exchange rates in order to determine the maximum expected discounted global, after-tax value of alternative strategies. Similar to the models of Huchzermeier (1991) and Huchzermeier and Cohen (1992a, 1992b), this article presents a strategic planning model that considers fixed operating costs, raw material costs, capacity variations, market prices, market demands, risk and long-term cost differentials. This article, however, presents a localized (as opposed to globalized) strategic model that incorporates exposure to financial risk (as opposed to exposure to exchange rate risk).

In this paper, a model is developed for localized strategic planning in the context of farm-level agricultural production; an individual broiler farm considers diversification into commercial aquaculture. Motivation for this research is first presented by a discussion of the operating environment and economic characteristics of both the broiler industry in the Mid-Atlantic region and the newly emerging aquaculture industry. When considering a long-term strategic planning horizon, some short-term fixed costs must be reclassified as variable costs because such costs are directly traceable to the use of specific production facilities over the long run. Also, diversification can potentially increase financial risk; thus, an operationalizable financial risk measure is an essential input into the strategic planning model. A model is formulated to evaluate the long-term economic feasibility of diversification of a broiler farm into commercial aquaculture. Specific implementation results are discussed.

THE NATURE OF THE PROBLEM

The Broiler and Aquaculture Industries

As a core industry in the Mid-Atlantic region's agricultural sector, broiler production has aided rural development by supporting farm income and creating employment. In specific states of the Mid-Atlantic region, broiler production contributes from 56% to 60% of rural household income (Taylor & Elterich, 1990). In the last decade, the broiler industry has experienced rapid expansion in both production and consumption due to better technologies and changes in consumer preference. Although the industry will continue expanding, the growth rate in the next decade is expected to be lower. In view of these changing circumstances, broiler growers face strategic decisions concerning diversification into alternative commodities as a method of creating an alternative income source and as a method of managing risk. An alternative commodity suggested for this purpose is commercial aquaculture (Gempesaw & Bacon, 1993).

Commercial aquaculture has several attractive features as an alternative commodity. Besides being a closely related product to broilers in terms of consumer product substitutability, future markets for aquaculture products are expected to expand significantly (Sandifer, 1988). In terms of production, commercial aquaculture has been one of the fastest growing agricultural commodities in the United States and is viewed as a future growth industry. Hybrid-striped bass (HSB) is an aquaculture product identified as having economic potential for farmers in the Mid-Atlantic region. New to the aquaculture product market, HSB commands a significantly higher price than broilers with producers expected to experience investment returns as high as 20% (Gempesaw et al., 1991). Studies suggest HSB as a potential candidate for aquaculture in the Mid-Atlantic region (Hodson et al., 1987) and indicate HSB as an alternative for broiler farmers considering product diversification (Gempesaw et al., 1991). Although the adoption of aquaculture in developing countries as a supplement to poultry farming has been shown to be technically feasible (Schroeder, 1980), economic feasibility is determined by several other factors such as input prices, availability of natural resources, market conditions, investment costs and risk considerations.

Due to output and contractual price agreements between broiler farmers and processors, variability of broiler farmers' earnings is typically extremely low, making broiler farming a low-risk agricultural activity. Commercial aquaculture is more risky. Aquaculture requires higher fixed overhead costs, causing more financial risk. An aquaculture farmer does not enjoy the contractual production arrangement characterizing broiler production (contracted production for a guaranteed demand market). The farmer is directly exposed to price fluctuations in the product market; however, farmers can expect to earn higher returns commensurate with the increased financial risk.

Because broiler farming is such a relatively low-risk operation, diversification of a broiler farm into an integrated broiler/HSB farming system can potentially boost profits while simultaneously exposing the farmer to higher financial risk. A primary direct benefit of poultry-aquaculture production systems, as observed in developing countries, is the reduction in variable aquacultural production costs. These benefits are partially attributable to the fact that poultry can be partially physically housed directly over aquaculture ponds, providing natural fertilization for plants, which finfish ultimately consume (Alsagoff, Clonts & Jolly, 1990; Schroeder, 1980). More importantly, another benefit of an integrated system is that the two production processes share fixed costs leading to economies of scope attributable to more efficient use of common resources.

Implementation of an integrated production plan under diversification should be preceded by a thorough evaluation of its economic feasibility to monitor the cost-benefit tradeoffs and to determine the optimal level of integration. This article provides a structured mechanism for such an evaluation by developing a mathematical decision model that serves two purposes: (1) evaluation of long-term economic benefits of diversification at an individual farm level and (2) establishment of optimal long-term production levels under diversification subject to financial risk considerations. The model provides an optimal strategy to pursue (i.e., diversify or not diversify), optimal production levels, and both optimal capacity requirements and optimal capacity utilization for the selected strategy.

Past Literature

Previous works in the application of mathematical programming to aquaculture include Alsagoff, Clonts and Jolly (1990) and Wilson, Shaftel and Barefield (1991). Alsagoff et al. (1990) analyzed long-term (ten years) economic viability of aquaculture farming, integrated with small wet-rice farms in Malaysia, by considering long-run biological, production, financial, and marketing constraints. The model focused on long-term policy implications rather than farm-level production decisions. Wilson et al. (1991) presented a medium-term planning model that enabled management of an aquaculture facility to develop optimal production schedules for a given technology, consistent with the requirement of economic feasibility. Their model determined medium-term production decisions of a pilot aquaculture facility that was not part of any diversified production system.

This article moves beyond these two previous works by integrating the strategic scope of Alsagoff et al. (1990) with the operational scope of Wilson et al. (1991). This article considers long-term production planning under diversified poultry/aquaculture systems and incorporates into the decision process the increased financial risk associated with diversified systems. This paper also generalizes work by Gempesaw and Bacon (1993). Through simulation, Gempesaw and Bacon evaluated the economics of output specialization and diversification in the production of broilers, HSB and catfish using data for representative farms over a ten-year planning horizon. Their simulation study generated, among key output variables, risk and return information for various diversification scenarios. As opposed to simulation, this paper develops closed-form optimizing models to evaluate the economic feasibility and appropriate level of diversification subject to risk tolerances predetermined by the decision maker. In addition, the model developed in this paper provides an optimization framework in which constraints regarding risk can be externally imposed.

MODEL FORMULATION

Measurement and Operationalization of Financial Risk

In this paper, financial risk is defined as variability of expected earnings. An operationalizable measure for risk is developed using the accounting concept of leverage. The concept of leverage deals with the effects of fixed operating and financial commitments on a firm's earnings. Variability of earnings is ascribed to a business' commitment to fixed obligations and its magnitude is a function of the level of fixed commitments and the scale of the production activity (Helfert, 1991). In the absence of fixed cost obligations, a change in production volume translates into a proportional change in profit, leaving the rate of return unaffected. Existence of fixed commitments distorts this relationship. For example, with fixed cost commitments, a 10% change in volume would cause more than a 10% change in earnings. Profit variability increases as fixed cost commitments increase.

Fixed commitments arise due to the inherent characteristics of the underlying production process and the manner in which the production process is financed. The degree of operating leverage (DOL) is the extent to which a production operation is loaded by fixed operating costs and is theoretically defined as:

$$\text{DOL} = \frac{\%\Delta \text{ Earnings Before Tax and Interest}}{\%\Delta \text{ Production Volume}} \tag{1}$$

DOL is a measure of the elasticity of income before interest and tax (EBIT), with respect to volume, caused by the existence of fixed operating costs (Helfert, 1991).

In addition to operating costs, firms face fixed interest commitments due to opting for debt over equity as a financing source. The existence of fixed interest costs affects the variability of a firm's earnings. In the absence of debt financing, any variation in operating income (EBIT) is translated directly into a proportional variation in net income. With fixed interest costs, a variation in operating income becomes magnified (or leveraged) into an exceedingly proportional change in net income. This effect, known as financial leverage, is measured by the degree of financial leverage (DFL) and is theoretically defined as:

$$\text{DFL} = \frac{\%\Delta \text{ Earnings Before Tax}}{\%\Delta \text{ Earnings Before Interest and Tax}} \tag{2}$$

A firm faces both operating and financial leverage. The magnified variations in net income include the combined effects of fixed-cost production methods and fixed-cost financial arrangements. The combined effect, defined as the degree of combined leverage (DCL), is the product of DOL and DFL. To derive an operational measure of the degree of combined leverage, define Earnings Before Tax (EBT) as EBT = $(r - vc)x - (FC + I)$, where r is selling price per unit, vc is variable cost per unit, FC is fixed operating costs, I is interest costs and x is production volume in units. Now,

$$\text{DCL} = \frac{\%\Delta \text{ EBT}}{\%\Delta \text{ x}} = \frac{d\text{ EBT}}{dx}\,\frac{x}{\text{EBT}} = \frac{(r - vc)x}{\text{EBT}} \tag{3}$$

where $(r - vc)$ is total contribution margin (CM) (i.e., sales − variable costs). Dividing both sides by a constant CM ratio (CM/sales) yields

$$\text{DCL}_S = \frac{1}{\frac{\text{EBT}}{rx}} = \frac{1}{\lambda} \tag{4}$$

where λ, the profit margin ratio, is

$$\lambda = 1 - \frac{vc}{r} - \frac{(FC + I)}{rx} = f(r, vc, (FC + I), x) \tag{5}$$

This surrogate measure of risk, λ, unveils the underlying determinants of risk. The parameters r and vc are usually exogenously determined in the product and input markets, respectively. They may be considered as surrogates for the externally induced component of risk reflected in λ. vc may also be influenced by the efficiency with which inputs are utilized internally. Therefore, the internally induced component of risk in λ may be defined as a function of fixed commitments (FC + I) and the scale of production x. Other parameters constant, as (FC + I) increases, λ decreases resulting in DCL_s increasing, indicating higher risk. Similarly, as x increases, λ increases resulting in DCL_s decreasing, indicating lower risk.

Generally, the level of fixed commitments is dictated by and incidental to investment and financial decisions. Thus, an opportunity for attaining a desired level of risk lies in varying the scale of production. Given (FC + I) implied by investment and financial decisions, the level of financial risk can be reduced by expanding the scale of production. Given a specified level of fixed operating and financial costs, to maximize λ (i.e., to reduce DCL_s), production volume should theoretically be infinitely large. However, as scale of production is increased, the reduction in risk is limited. As volume becomes arbitrarily large, DCL_S approaches $r/(r - vc)$. This result signifies the practical impossibility of a risk-free venture even with an infinite expansion in production.

In reality, practical factors force production levels to be within feasible ranges. If a lower bound is imposed on the profit margin, reflecting the maximum level of risk the entrepreneur is willing to tolerate, then a lower bound is implicitly imposed on production volume. Let l denote the minimum acceptable λ (i.e., maximum tolerable risk) for a given production operation. From equation (5), $\lambda \geq l$ imposes the following production volume constraint:

$$x \geq \frac{(FC + I)}{r(1 - l) - vc} \tag{6}$$

Equation (6) can subsequently be used as a risk constraint in aggregate production planning models for strategic decisions in various production decision alternatives.

Model Formulation

The model evaluates the economic benefits of a broiler grower diversifying into aquaculturally produced HSB. The model assumes each of these two products can be produced in a nondiversified system (i.e., a system that produces only broilers or only HSB) and all contribution margins and costs incurred in a nondiversified system are known. Diversification of a broiler farm into an integrated broiler/HSB facility has two potential economic advantages: (1) certain fixed costs are shared between the two types of production systems and (2) a diversified system generates a per-unit variable production cost savings in HSB. However, diversification also generates increased financial risk.

The model evaluates the economic benefits of a diversified production system versus nondiversified production systems. If diversification is economically beneficial and feasible with respect to risk tolerance, the model simultaneously determines the optimal level of diversification (i.e., how many ponds should be built?) and the corresponding period production quantities for HSB. Because broiler production is fixed by contractual agreement between the farmer and a processor, production quantities and associated costs of broiler production are viewed as model input parameters. A typical broiler production cycle is about two months (8.5 weeks), generating approximately six discrete production cycles per year and sixty discrete periods over a ten-year planning horizon. HSB fingerlings are stocked once per year, generating one production period per year or ten periods during a ten-year planning horizon.

MODEL PARAMETERS

i = product index; $i = 1$ denotes the broiler product, $i = 2$ denotes the HSB product,

h_i = number of production periods associated with product i during the ten-year planning horizon ($h_1 = 60$, $h_2 = 10$),

cm_{it} = contribution margin per unit of product i in period t, in a nondiversified system,

d_{it} = market demand for product i in period t,

oc_{it} = operating costs of a type i production facility in period t; a type 1 facility is a broiler house, a type 2 facility is a pond system,

fct_i = capital fixed costs traceable to a type i facility in a nondiversified system,

fcn_i = capital fixed costs, nontraceable to a type i facility but traceable to product i, in a nondiversified system,

α_t = capital fixed costs, allocated to year t, that are traceable to a pond system in a nondiversified system,

fcs = capital fixed cost savings under a diversified broiler/HSB production system,

γ_t = proportion of fct_2 allocated to period (year) t,

r_t = per-pound revenue from the sale of HSB in year t,

vc_t = per-pound variable production cost of HSB in year t, in a nondiversified system,

vcs_t = per-pound variable cost savings in HSB in year t attributable to HSB produced in an integrated broiler/HSB system,

cap = annual production capacity of a pond system,

b = number of broiler houses used in the contractual production of broilers,

l = minimum desired profit margin from HSB production.

Variables:

Q_t = production quantity of HSB (pounds) in year t,
S_t = production shortage of HSB (pounds) in year t,
X_t = number of pond systems used in year t,
P = number of pond systems to be built for potential use throughout the planning horizon,
W = strategic 0/1 variable; $W=1$ if diversification into the HSB product, 0 otherwise.

Formulation:

$$\text{MAX} \sum_{t=1}^{h_1}[cm_{1t}d_{1t} - oc_{1t}b] - fct_1 b - fcn_1$$

$$+ W\left[\left(\sum_{t=1}^{h_1} (cm_{2t} + vcs_t)(Q_t - S_t) - oc_{2t}X_t\right) - fct_2 P - fcn_2 + fcs\right] \quad (7)$$

subject to:

$$d_{2t} = Q_t + S_t \qquad t = 1, \ldots, h_2 \quad (8)$$

$$Q_t \leq \text{cap } W\, X_t \qquad t = 1, \ldots, h_2 \quad (9)$$

$$X_t \leq W\, P \qquad t = 1, \ldots, h_2 \quad (10)$$

$$Q_t \geq \frac{W(oc_{2t}X_t + \alpha_t P_t + \gamma_t)}{r_t\,(1 - l) - vc_t} \qquad t = 1, \ldots, h_2 \quad (11)$$

$$S_t \geq 0;\ X_t,\ P \geq 0 \text{ and general integer; } W \text{ integer } 0/1$$

Equation (7) represents total contribution to profit, less all operating and capital costs, plus variable cost savings in HSB production and capital cost savings if diversification occurs. Equation (8) defines annual production and shortages of HSB in terms of market demand. Equation (9) restricts annual production of HSB to no more than maximum annual capacity. Equation (10) restricts the number of ponds used annually to no more than the number available over the entire planning horizon. Equation (11) is the application of the risk constraint of equation (6). Equation (11) forces annual production of HSB to a minimum level so that the financial risk associated with HSB production does not exceed the pre-specified maximum tolerable level.

The objective function of the model may be either total before-tax profit over the planning horizon or the present value of before-tax profit. As the planning horizon encompasses a longer time span, use of present value is more appropriate. When present value is used as an objective function, the model is comparable to the NPV approach in capital budgeting, with a major exception being that the model does not evaluate present value on an after-tax basis which is normally the case in NPV. Use of present value involves discounting the parameters for contribution margins and fixed operating costs at an appropriate discount rate. However, it should be noted that the major distinguishing feature of the strategic model lies in its optimization capabilities.

IMPLEMENTATION AND RESULTS

The model is applied to farm-level strategic planning where a broiler farm is considering diversification into commercial HSB aquaculture production. Data construction, implementation results and sensitivity analysis are now discussed.

Data Construction

Initial year-one input parameters for the model were constructed from data on prices, production costs and production capacity for representative broiler and HSB farms, as used in the simulation model of Gempesaw and Bacon (1993). Broiler prices and agricultural production expenses were subject to annual increases at forecasted growth rates during the years 1991–2000 (i.e., a ten-year planning horizon) provided by WEFA (1991). Given a survey of broiler farmers in the Mid-Atlantic region (Bacon, Halbrendt & Gempesaw, 1990), a representative broiler farm was assumed to consist of 3 broiler houses. Demand for broilers in each production period (8.5 weeks) was assumed to be derived from a contractual agreement with a processor, and equal to the production capacity of three broiler houses.

Tables 1 and 2 present cost estimates constructed from the simulated data of Gempesaw and Bacon (1993). Variable and fixed operating costs for both broiler and HSB were also allowed to increase at the forecasted growth rates of agricultural production expenses during the years 1991–2000 provided by WEFA (1991). Decisions concerning capacity allocations are made at the beginning of the planning horizon so that capital costs remain constant throughout the planning horizon. In computing capital costs for the broiler farm and the aquaculture farm, it was assumed that the farmer finances half of the required investment using external debt. An interest cost of 5% and a 0.187% annual property tax were assumed.

Because commercial aquaculture is a relatively small sector in U.S. agriculture, data on sectoral characteristics, let alone farm-level data, are scarce. In the absence of such data, price forecasts for HSB were developed using the forecasted annual growth rates in broiler prices. The justification lies in the fact that the two product types are related in that major determinants of their price dynamics, such as consumer taste and income, influence their prices in a similar fashion. To develop annual demand forecasts for HSB, initial demand was assumed equal to the ca-

TABLE 1

Initial Year 1 Cost Estimates for Broiler Production

Type of Cost	Item	Cost
Variable	labor	$0.008 per pound
Fixed Operating	utilities	$ 600
	maintenance	100
	other	320
		$ 1,020 per house per period
Fixed Capital		
Traceable	house	$ 50,000
	land	1,895
	interest on capital	25,474
	property tax	1,905
		$ 79,274 per house over planning horizon
Nontraceable	tractors	$ 59,375
	trucks	18,750
	all-terrain vehicle	8,750
	interest on capital	17,375
	property tax	1,300
		$ 105,550 over planning horizon

pacity of a representative HSB production facility (i.e., four five-acre pond systems) (Gempesaw, Bacon & Wirth, 1992). Using demand growth rates for fish products over the past decade (WEFA, 1991), initial 1991 demand was allowed to increase by an annual growth rate of 2.5%.

One of the major benefits of diversification relates to the reduction in the variable costs of HSB production. For the purpose of this study, a $ 0.05/lb savings in variable cost of HSB (i.e., 3.5% of variable cost) was assumed. All input parameters for the model for the first year of the planning horizon are summarized in Table 3.

Implementation Results

The optimal production structure recommends the integration of broiler farming with HSB production. Optimal activity levels within the integrated system amount to full utilization of three broiler houses and par-

TABLE 2

Initial Year 1 Cost Estimates for HSB Production

Type of Cost	Item	Cost
Variable	labor	$ 0.128 / lb
	fingerlings	0.750
	feed	0.500
	harvesting/hauling	0.050
		$ 1.428 / lb
Fixed Operating	utilities	$ 2,888
	maintenance	656
	other	682
		$ 4,226 per pond per year
Fixed Capital		
Traceable	pond	$ 20,839
	wells	6,250
	land	9,475
	aerators	5,500
	interest on capital	9,829
	property tax	735
		$ 52,628 per pond over planning horizon
Nontraceable	tractors	$ 59,375
	trucks	18,750
	all-terrain vehicle	8,750
	boat	4,000
	feeder	5,000
	testing devices	3,600
	backup aerators	2,000
	building	10,000
	shed/lab	10,000
	interest on capital	24,200
	property tax	1,810
		$ 147,485 over planning horizon

TABLE 3

Initial Year 1 Parameter Estimates Under Diversified Production

Broiler Production		**HSB Production**	
Parameter	**Estimate**	**Parameter**	**Estimate**
cm_{11}	0.026	cm_{21}	0.922
vc_{11}	0.008	vc_{11}	1.428
—	—	vcs_1	0.0500
d_{11}	400,005	d_{21}	105,000
—	—	cap_1	26,250
oc_{11}	1,020	oc_{21}	4,226
fct_1	79,274	fct_2	52,628
fcn_1	105,550	fcn_2	147,485
—	—	fcs	105,550
—	—	γ_1	14,749
—	—	α_1	4,316
—	—	l	10%

TABLE 4

Optimal Period Production Levels Under Diversification

Year	Pond Systems Used	HSB Production (lbs)	Broiler Houses Used	Broiler Production (lbs)
1	4	105,000	3	400,005
2	5	107,625	3	400,005
3	5	110,316	3	400,005
4	5	113,074	3	400,005
5	5	115,900	3	400,005
6	5	118,798	3	400,005
7	5	121,768	3	400,005
8	5	124,812	3	400,005
9	5	127,932	3	400,005
10	5	131,131	3	400,005

Number of pond systems to be built = 5
Total before-tax profit = $ 548,435
PV of total before-tax profit = $ 390,692

tial utilization of five ponds. Table 4 presents the optimal production plan.

Given a variable cost savings in HSB of 3.5%, the optimal diversified production structure generates a total before-tax profit of $548,431 (PV = $390,692) over a ten-year planning horizon. A nondiversified three-house broiler production system would generate a total before-tax profit of $70,875 (PV = $29,554) over the ten-year planning horizon. A nondiversified five-pond HSB production system would generate a total before-tax profit of $306,010 (PV = $213,436) over the ten-year planning horizon. Thus, a diversified broiler/HSB production system generates an additional $171,546 before-tax profit over the ten-year planning horizon than the combined profits of separate (nondiversified) broiler and HSB farms. The significant boost in earnings of the diversified plan stems from two cost-saving factors: utilization of shared resources (accounting for 62% of the increased profits) and variable cost savings in the production of HSB (accounting for 38% of the increased profits).

Sensitivity Analysis

Sensitivity of the optimal production structure was analyzed with respect to changes in variable cost savings in the production of HSB, contribution margins of HSB, pond operating costs and market demands for HSB.

Variable cost savings. Variable cost savings associated with diversified broiler/HSB production depends primarily on the quality of pond management. Experimental station ponds in Israel have observed that, with the use of animal manure alone, cost savings as much as the full feed cost (35% of variable production cost) is possible (Schroeder, 1979). However, given the sensitivity of HSB to environmental factors and U.S. government restrictions on feed inputs, this maximum level of savings is not likely to be realized in U.S. commercial ponds. The assumed 3.5% savings in HSB variable production cost is a plausible benchmark figure for a new farmer with no aquaculture experience; higher savings would be expected as the farmer becomes more experienced. The optimal production plan remained optimal as variable cost savings ranged from 0% (no variable cost savings) to 35% (full feed cost) of HSB variable production cost. A one percent increase in variable cost savings (expressed as a percentage of HSB variable production cost) generated an increase of approximately $18,900 in the maximum net total profit.

Contribution margins of HSB. The optimal production plan remained optimal for any increase in the current estimated annual HSB contribution margins, and for any decrease of up to 7.5% of the current estimated annual HSB contribution margins. Within these ranges, a one percent increase/decrease in the estimated annual contribution margins of HSB generated an increase/decrease of approximately $9,400 in maximum net total profit.

Pond system operating costs. The optimal production plan remained optimal for any decrease in the current estimated annual operating costs of pond systems, and for any increase of up to 8% of the current estimated annual operating costs. Within these ranges, a one percent increase/decrease in the estimated annual operating costs of pond systems generated a decrease/increase of approximately $2,300 in maximum net total profit.

Market demand for HSB. The optimal level of diversification is the construction of 5 pond systems for potential use over the planning horizon. This optimal level of diversification remained optimal for increases of up to 12%, and for decreases of up to 3%, in projected annual market demands for HSB. Indeed, the model is sensitive to relatively small decreases in projected market demands for HSB. However, it is important to note the following: If market demands for HSB in each year of the planning horizon fell as much as 17% from their current projected levels, a diversified production system operating five pond systems would still be more economically efficient than two nondiversified systems.

CONCLUSIONS

In this paper, a decision support model for strategic planning was developed. The model was geared to decisions involving long-term planning horizons and incorporated considerations of financial risk and capacity variations, two essential ingredients of long-term strategic decisions. The model was implemented to evaluate an agricultural diversification decision in which a broiler farm considers diversification into commercial aquaculture. Results indicated that a diversification plan significantly increases the profitability of the farm while keeping the potential financial risk within a desired tolerable limit.

The measure of risk used in the model for evaluating diversification focuses only on the financial risk related to HSB production and not on the overall financial risk associated with the entire broiler/HSB diversified production system. One might expect that the overall risk measure for an integrated system will be lower than the risk of an independent aquaculture operation and higher than the risk of an independent broiler operation. A future research direction having both methodological and empirical interest is the derivation of an aggregate risk measure for the integrated system and incorporation of the aggregate measure into the aggregate planning model by restricting production levels on both product types. Preliminary work in this area indicates that such an aggregate measure significantly increases model complexity.

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