Dynamic Assessment of Rural Dairy Cooperative Feasibility to Improve Livelihoods in South-Central Mexico

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An SD model of biophysical and socioeconomic processes represents the aggregate community goat flock and a processing and marketing cooperative in highland communities near Xalapa, Mexico. Developed through a group model building process with researchers from Mexico's Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, the model is used to assess strategies to increase net income from caprine production through cooperative processing of aged cheeses. Our analyses indicate that manufacture of goat milk products by the cooperative could increase community net income from caprine activities under a variety of environmental and market conditions, including significant demand shocks—if these shocks occur after the cooperative is fully operational. These analyses also indicate potential risks and factors that could limit cooperative success: market size and reliability, cooperative management policies, production costs, and flock composition and productivity.

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1. Introduction

In the Mexican state of Veracruz, rural communities struggle with food insecurity, unemployment, and variable agricultural incomes. Market uncertainties often limit economic development opportunities in these rural communities. Poverty alleviation in these regions is contingent on improving food security and achieving rural economic growth (Blake 2003). Specifically, an important component of poverty reduction is the development of income opportunities for poor rural families. One strategy to provide higher incomes may be the production of higher-value products. These products, when manufactured and marketed by local farmer collectives or cooperatives, have the potential to improve rural livelihoods through improved local and regional market potential and access, reduced market uncertainty, and greater net incomes from agriculture (Nicholson et al. 1998; Holloway et al. 1999).

In the highland community of Micoxtla, near the city of Coatepec, the majority of inhabitants work primarily in agricultural production. The principal products sold are milk, young goats for meat (*cabrito*), and eggs after fulfilling household consumption needs. However, production is low and net incomes are modest. The *Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias* (INIFAP) found that most Micoxtla families struggle with seasonal food insecurity and economic instability (INIFAP 2006b). An array of traditional but highly-valued products is produced in Micoxtla and could allow community members to compete in higher-value local and regional markets.

Premium cheese production in Micoxtla could provide an opportunity to increase household earnings from dairy products, an idea originating in the community itself. However, the development of this strategy requires financial resources and faces numerous risks arising from dynamic biological, economic and social processes. Our objective was to assist the community to assess the feasibility of value-added goat's milk production, processing, and marketing through establishment of a dairy cooperative.

2. Reference Mode Behaviors

Although historical data are unavailable, producer perceptions suggest that current net incomes from caprine enterprises are low. Fluctuations arise from seasonal rainfall and forage supply, and milk price variation (blue line in Figure 1). The *status quo* behavioral pattern is yearly seasonal oscillation, which is sustained over time. The desired future behavior is to increase net income from the flock as additional income is received from cooperative raw milk sales and dividend receipts. The desired behavioral mode is goal seeking with yearly seasonal oscillations. A 20-yr time horizon was chosen to assess future patterns of behavior after initiating dairy cooperative operations. The 20-yr time horizon is sufficient to capture major changes (e.g., collapse) in net income from limiting factors such as forage supply and market instability.

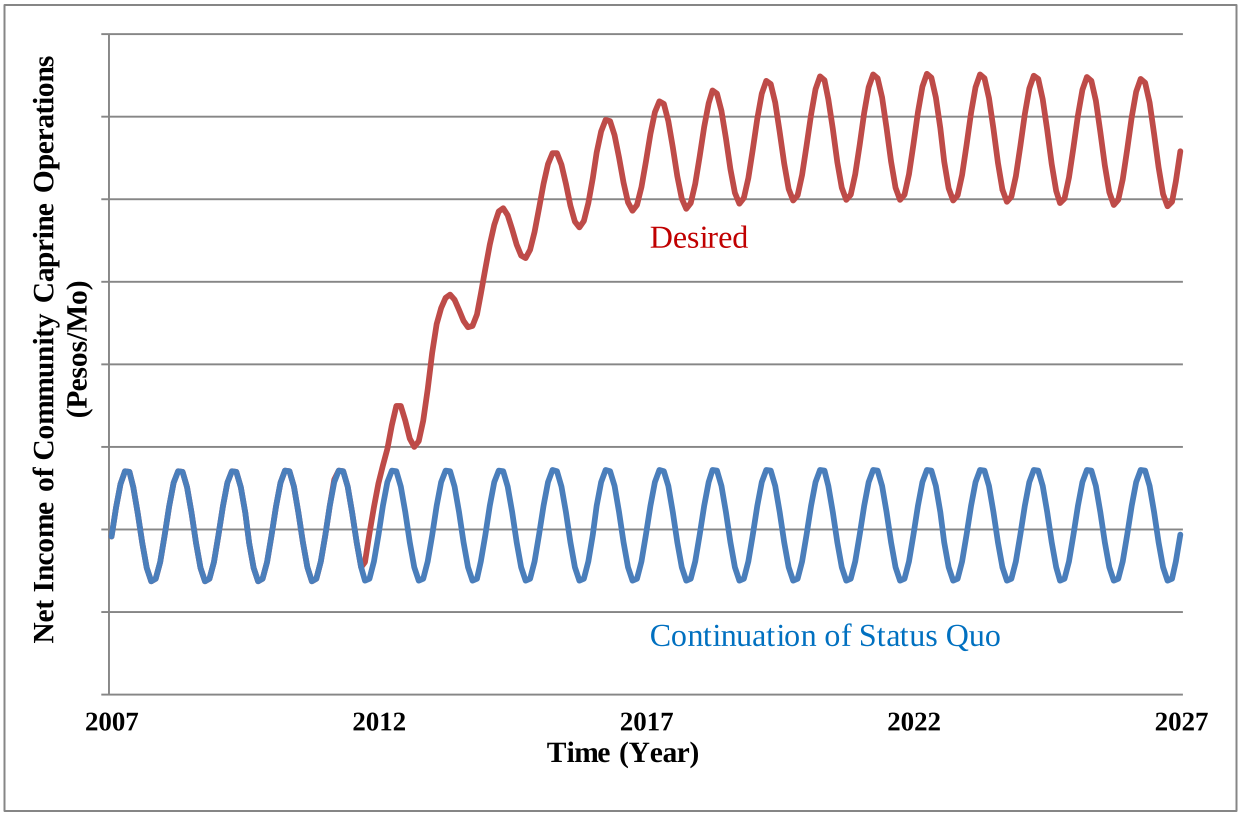

Figure 1: Monthly net incomes of aggregate community caprine operations. Desired future behavior and continuation of the *status quo* are shown.

Feedback Structure

A causal loop diagram depicts the primary interactions and constraints to the economic success of value-added cheese production for a rural cooperative (Figure 2). There are several key feedback pathways for the five income generation activities associated with goat production in Micoxtla. These activities include milk sales in the nearby town of Xico, cooperative milk sales, cooperative dividend payments, sales of culled animals, and male kid (*cabrito*) sales. Each activity creates a reinforcing feedback loop that would promote growth. A principal balancing feedback loop in production is seasonal forage availability, but additional balancing feedback processes arise from the market.

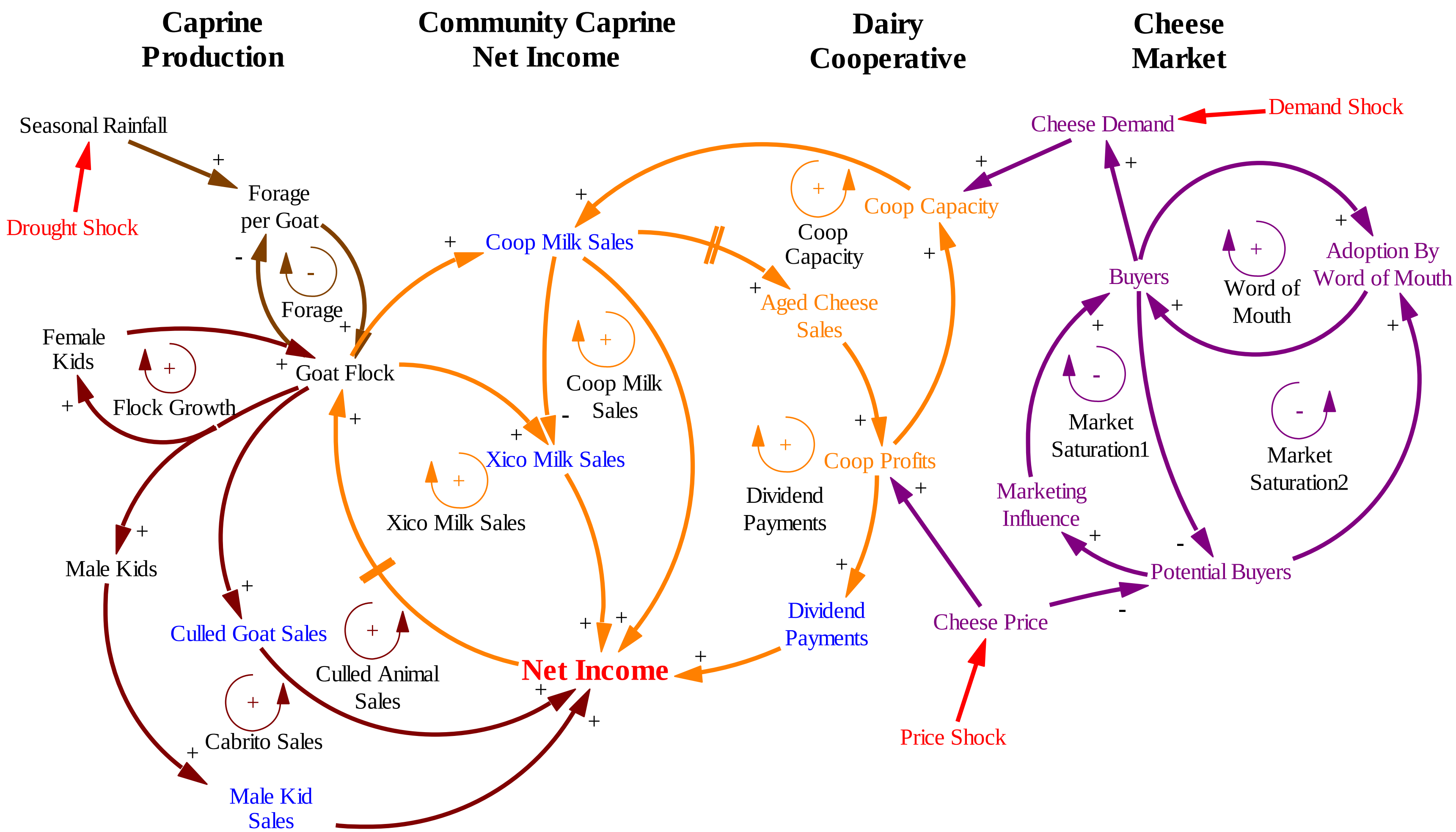

Figure 2 CLD displays the sources of producer income generation from caprine operations as underlined variables. The basic feedback structure of the goat flock, community caprine net income, dairy cooperative, and the cheese market are shown. The network of feedback structure is hypothesized to cause the behavior over time depicted in the reference mode.

The *status quo* behavior of the reference mode arises primarily from seasonal patterns of rainfall. However, economic feedback loops include milk sales in Xico, *cabrito* sales and culled animal sales. These three activities collectively make up the animal reinvestment feedback loop (not pictured) through the causal link between net income and goat flock. Net income from these activities is low or negative, which, combined with rainfall-induced forage limitations, constrains animal reinvestment and flock size to the oscillations depicted in the *status quo*.

In contrast to the *status quo*, the desired pattern of behavior is growth in net income, albeit with continued seasonal oscillations. Additional feedback loops are active in the scenarios to assess feasibility of the cooperative. Cheese market feedback loops (market saturation 1, market saturation 2, and word of mouth) are activated by initial marketing of value-added product, which also initializes cooperative operations. Cooperative-related feedbacks include milk sales, dividend payments, and capacity feedback loops. Rapid growth in net income is hypothesized from dividend payments after the cooperative startup period.

Two primary factors are hypothesized to balance system growth with the cooperative: local cheese market saturation and milk production potential. The cooperative is constrained by the size of the potential market for aged cheese in the market saturation feedback loops. The cooperative capacity, cooperative milk sales, and dividend payments feedback loops are also influenced by market size, which limits net income and flock reinvestment by goat farmers. Milk production is constrained by flock size through the forage, flock growth, and animal reinvestment feedback loops.

3. Value-Added Cooperative Model

The value-added cooperative simulation model was designed as part of a group model-building exercise with INIFAP staff in Xalapa, Mexico. The simulation model was formulated in Spanish to facilitate subsequent use by INIFAP. The model represents the aggregate goat flock in Micoxtla and a rural value addition and marketing cooperative. The model consists of nine modules: 1) community goat flock, 2) forage resources, 3) milk allocations, 4) cooperative cheese production, 5) cooperative productive capacity, 6) cooperative management and decisions, 7) aged cheese market, 8) producer net income expectations, and 9) user interface. A description of these modules follows.

Community Caprine Production

The stock-flow structure of the goat production module consists of a doe aging chain divided into three stocks: *cabritas* (young does), weaned *cabritas*, and adult does. An additional stock of *cabritos* (young bucks) is also part of the goat production stock-flow structure but is not included in the aging chain because all *cabritos* are either sold or consumed locally. The primary management decision rules associated with the goat flock include reinvestment in adult does and variation in the adult doe-culling rate. Desired does and doe purchase formulations were adapted from the production capacity formulation (Sterman 2000).

Forage Resources
The animal aging chain is connected to the forage resources module through two variables: forage available per caput and fractional forage needs satisfied. The ratio of available forage to reference forage per goat defines the fraction of forage needs that are met. This fractional forage condition nonlinearly affects the kidding rate, adult goat mortality, milk production, and desired forage resources via their respective reference multiplicative effect formulations in other modules. This forage resources formulation does not account for forage quality. Management decisions in this module include fertilizer applications to forage crops and land area in forage production. Both generate production costs. Labor costs are also calculated as a function of forage production.

Average yearly rainfall patterns from 1961 to 2003 obtained from the climatology station in Teocelo, Veracruz served as a proxy for seasonal variation in forage productivity (INIFAP 2006a). The ratio of average individual monthly rainfall to overall average monthly rainfall affects forage productivity in a multiplicative formulation.

Milk Allocation
The milk allocation module (Figure 3) represents the use of fluid milk for feeding young goats, for household consumption, and for sales income. It is linked to the goat production module via the stocks of adult does, c*abritos* and c*abritas*, and to the forage resources module through forage availability. Households decrease milk consumed when milk prices are higher. Milk prices can fluctuate up to 50% between the dry season and rainy season based on the quality, supply, and demand for milk (Holmann 2001). The assumption was also made that producers would first fill the demand of the cheese cooperative before selling excess milk in Xico.

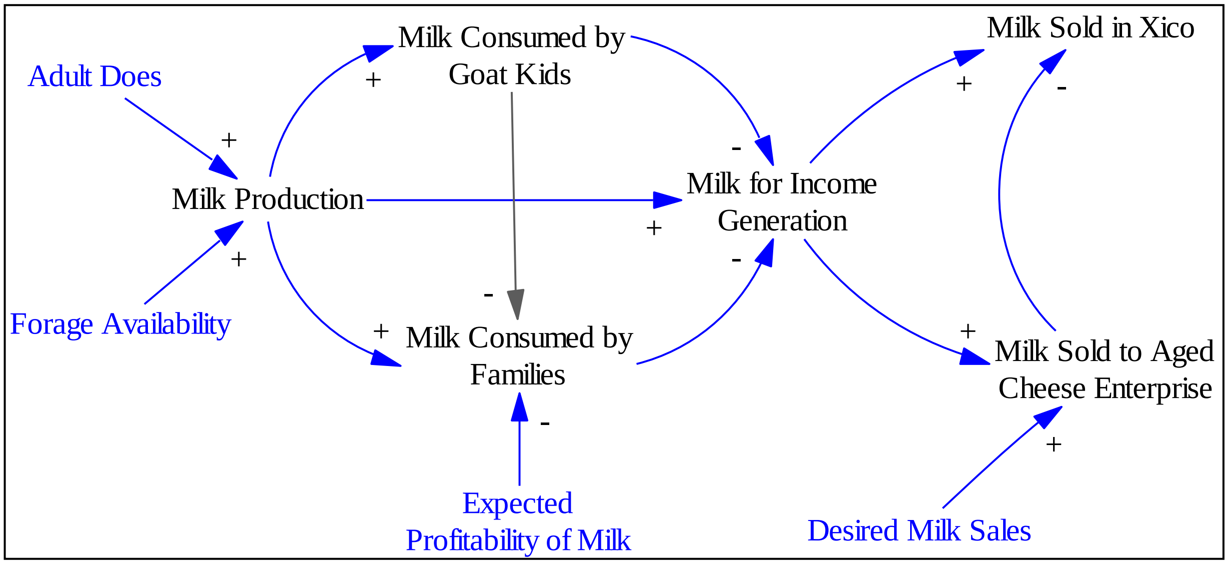

Figure 3 A simplified structure for milk allocation. Fluid milk is consumed by goat kids and the families raising them. Surplus milk production is allocated to income generation, and is either sold in Xico or to the aged cheese cooperative.

Dairy Cooperative

The cooperative (Figure 4) is independent of animal production and milk sales. The cooperative buys fluid milk from farmers and incurs expenses for cheese production, storage, and marketing. It is assumed that the objective of the cooperative is to maximize economic returns to farmers who sell raw milk to the cooperative. Therefore, after capacity investments are made, surplus is paid to participating farmers as dividends or as a combination of dividends and higher milk prices.

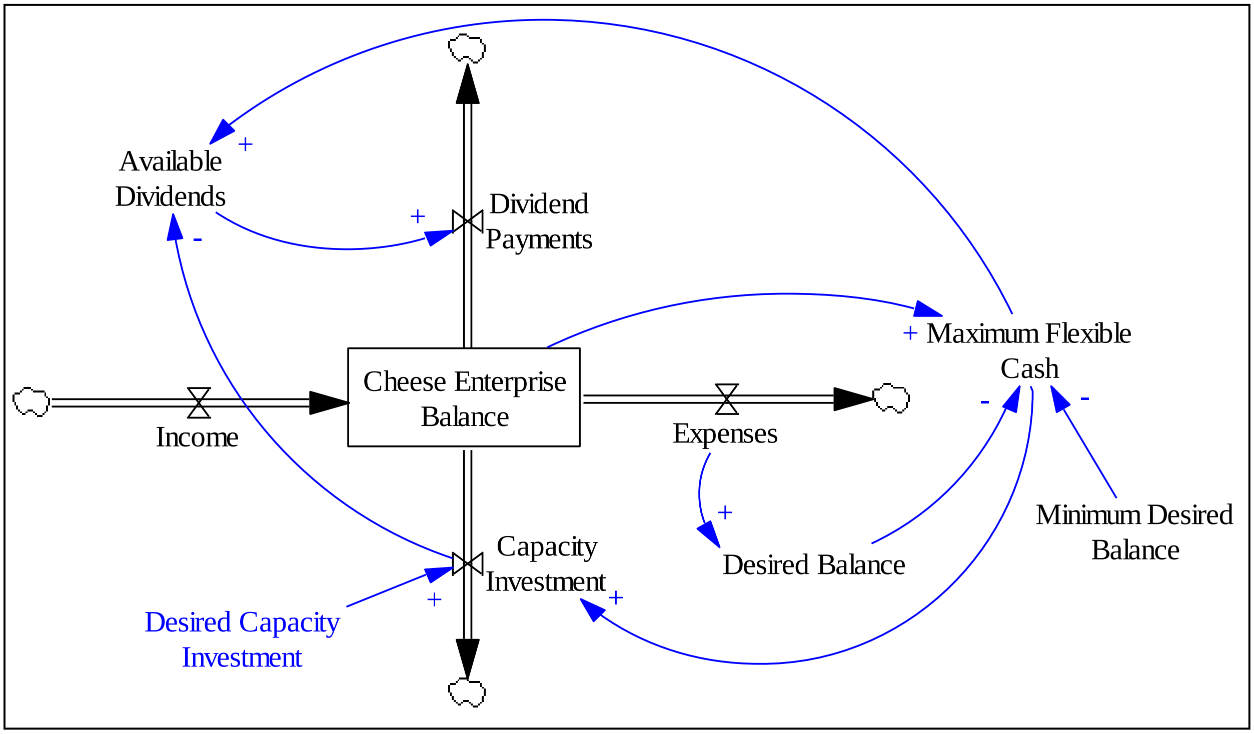

Figure 4 Simplified structure for cheese cooperative decisions and cash holdings. This single stock structure computes the difference between income and expenses over time given the cooperative management policies.

The overall measure of financial performance for the cooperative is net income including expansion investments, but excluding depreciation[1]. Cooperative income and expenses depend on cheese manufactured. The capacity investment and dividend payments outflows are critical to the performance of the cooperative. The maximum flexible cash decision rule (Figure 4) assumes that a management objective is to maintain sufficient cash on hand to cover expected expenses for future months to prevent economic crises due to seasonal market uncertainties. The cooperative invests in capacity when there is a desired investment in capacity (from productive capacity module) and sufficient flexible cash to make the investment. It is assumed that the cooperative will always fulfill desired capacity investments before paying dividends to farmers.

[1] Physical depreciation of the cooperative's infrastructure is included. A reviewer's suggestions to better delineate the different elements of cooperative financial performance, including an income statement with depreciation, a cash flow statement and a balance sheet analysis would enhance the analysis of the cooperative as a business model.

If excess flexible cash is available after fulfilling desired capacity investments, dividend payments would be made.

Productive Capacity of the Cooperative

The cooperative initializes operations by making a small investment in production capacity at the same time that marketing commences (year two of the simulation). Following an exogenous initial investment, the capacity expansion structure acquires capacity endogenously when there is a desired capacity investment and sufficient flexible cash. Desired capacity investment responds to expected demand for aged cheese. Capacity utilization is a function of the ratio of expected orders to capacity in a reference multiplicative formulation. It assumes that the cooperative will lower capacity utilization by decreasing milk purchases when cheese demand is low.

Aged Cheese Manufacture

Once productive capacity is acquired, purchased milk flows into the two-stock cheese manufacturing process. After maturation, the product is transferred to aged cheese inventory. It exits this stock through the sales rate, which is a fuzzy MIN formulation that responds to consumer demand and available inventory (Sterman 2000). The sole source of income for the cooperative is cheese sales to consumers. Variables depicting production costs, storage costs, and marketing costs are determined by the quantity of cheese being produced, stored, and sold, respectively.

Market for Aged Cheese

The market for cheese produced by the cooperative is in Xico, where buyers are hotels and restaurants serving the growing tourism industry. The market demand structure creates logistic growth in the number of actual buyers (e.g., restaurants, hotels, and private households). This directly affects the product demand, the desired cooperative production capacity, and capacity utilization. The structure was selected and adapted from the Bass Diffusion Model (Bass, 1969, as cited in Sterman 2000), which is commonly used to estimate new product sales during the product growth phase.

Net Income Expectations and Decisions for Goat Producers

Monthly net cash operating income derives from *cabrito* sales, culled goat sales, milk production, and dividend receipts. These variables also represent farmer expectations about the net incomes of goat production and milk production, and influence producer decisions about the reinvestment of net cash operating income in different goat enterprises (e.g., goat purchases), the culling rate and household milk consumption.

4. Simulated Interventions and Shocks

Because the objective of this analysis is to evaluate the potential of the cooperative to increase the goat farmer net incomes (rather than cooperative net income *per se*), the net cash operating income of the aggregate community flock in Micoxtla (from Figure 1) is used as the primary indicator of success. Cooperative cash holding is used to assess cooperative capacity to fulfill the overall objective. The conditions for cooperative success are assessed under average operating conditions and for different market shocks.

Baseline
As a point of departure, historical and projected future patterns of behavior over time were simulated. Under this simulation, Micoxtla animal and milk production patterns continue as they have historically without cooperative operations, meaning that average caprine income is low and characterized by substantial seasonal variation (Figure 5). This simulation is equivalent to the continuation of the *status quo* in the reference mode graph (see Figure 1).

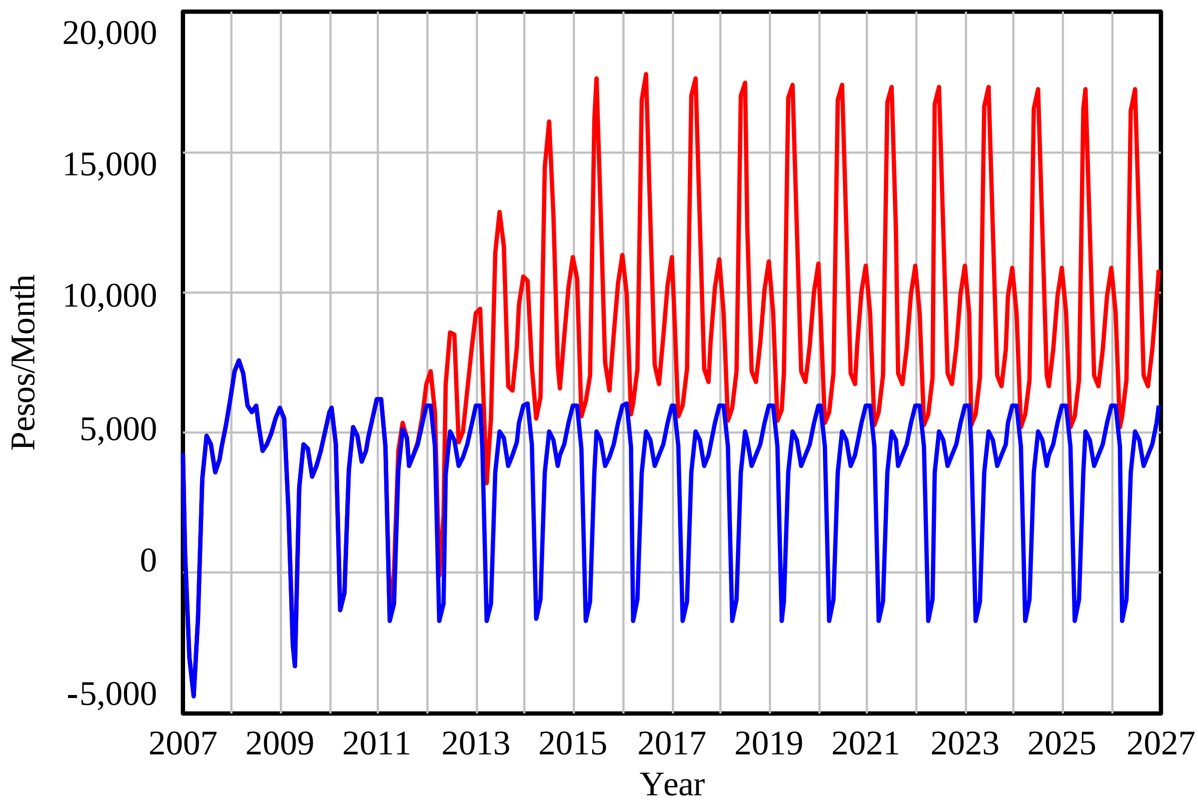

Figure 5 Monthly net cash operating income of community caprine operations. The base simulation (blue line) is compared to the cooperative simulation (red line).

The simulation begins during the dry season of January 2007. Oscillatory behavior is observed due primarily to fluctuations in forage availability from seasonal rainfall. It directly affects flock size and flock net income via nonlinear effects on the rates of birth, culling, adult doe death, and milk production. The simulation results are also influenced by seasonal fluctuations in the price of raw milk. Many initial stock and parameter values are chosen so that the model would initialize in dynamic equilibrium without exogenous disturbances (e.g., rainfall and milk price). Therefore, the oscillatory pattern repeats as feedback mechanisms continually adjust to variation in forage productivity.

The base simulation is consistent with traditionally low net margins reported by Micoxtla caprine producers. Due to limited milk production during the dry season, community caprine activities are not profitable for a period of about two months (April and May) each year. The size of the community goat herd oscillates around approximately 125 adult does. The simulated cumulative net margin of the community goat herd during the 20 year time horizon (2007 to 2027) is about

$905,000 pesos, primarily from sales of milk, *cabrito*, and culled animals. Milk is most important, accounting for 78% of total income, followed by sales of *cabrito* (19%) and culled goats (3%). This distribution qualitatively approximates the *status quo* for caprine activities in Micoxtla (INIFAP 2006b).

Aged Cheese Cooperative Feasibility

The financial feasibility of a cooperative itself and its contribution to household net income are evaluated through an assumed initial investment in cheese production and marketing capacity. In contrast to the simulated baseline behavioral pattern, cooperative operations (Figure 5) result in increases in the monthly net income of community caprine activities from 2011 to 2015, before reaching a sustained series of oscillations at greater average net income. The qualitative shape of the oscillations also changes between the base and cooperative simulations due primarily to cooperative dividend payments.

Once market demand and production capacity are established, the cooperative begins buying and processing fluid milk from farmers at the local market price. Cooperative productive capacity, market demand, or milk supply can limit the quantity of milk processed by the cooperative. The importance of these limitations depends on season and simulation time.

Oscillatory behavior in the monthly net income of community caprine activities ensues as dividends payments are received seasonally from the cooperative after it becomes solvent. Thus, the base and cooperative simulations diverge in 2011, more than two years after cheese manufacture begins. Production and sales delays in the cheese supply chain prevent earlier cooperative solvency. The monthly net income of community caprine activities reaches its maxima by 2015, after which the market demand for aged cheese limits further growth. Lack of rainfall limits milk production during a portion of each dry season. Rainy season milk supply is constrained by the size of the adult doe flock[2] and by milk productivity. The relationships between forage availability and the rates of milk production, birth, death, and household milk consumption are included in multiple balancing feedback loops affecting dry season milk supply.

The cumulative net income of community caprine activities is 1.9 million pesos, which is 1.0 million pesos larger than the base simulation during the 20-yr time horizon. Thus, potential exists for the cooperative to double net incomes in the community under the simulated circumstances. After cooperative solvency is attained, the least profitable points in the cooperative simulation are approximately equal to the most profitable ones in the base simulation (from Figure 5). Producers benefit because cooperative caprine operations are profitable throughout the year. In addition, the pronounced seasonal difference in dividend payments after achieving solvency is a result of seasonal patterns of cheese production. The net income pattern (excluding dividend payments and capacity investments) of the cooperative (Figure 6) is also seasonal.

[2] Flock size is affected by the rates of culling and doe purchase, which are both management variables that are adjusted based on net income.

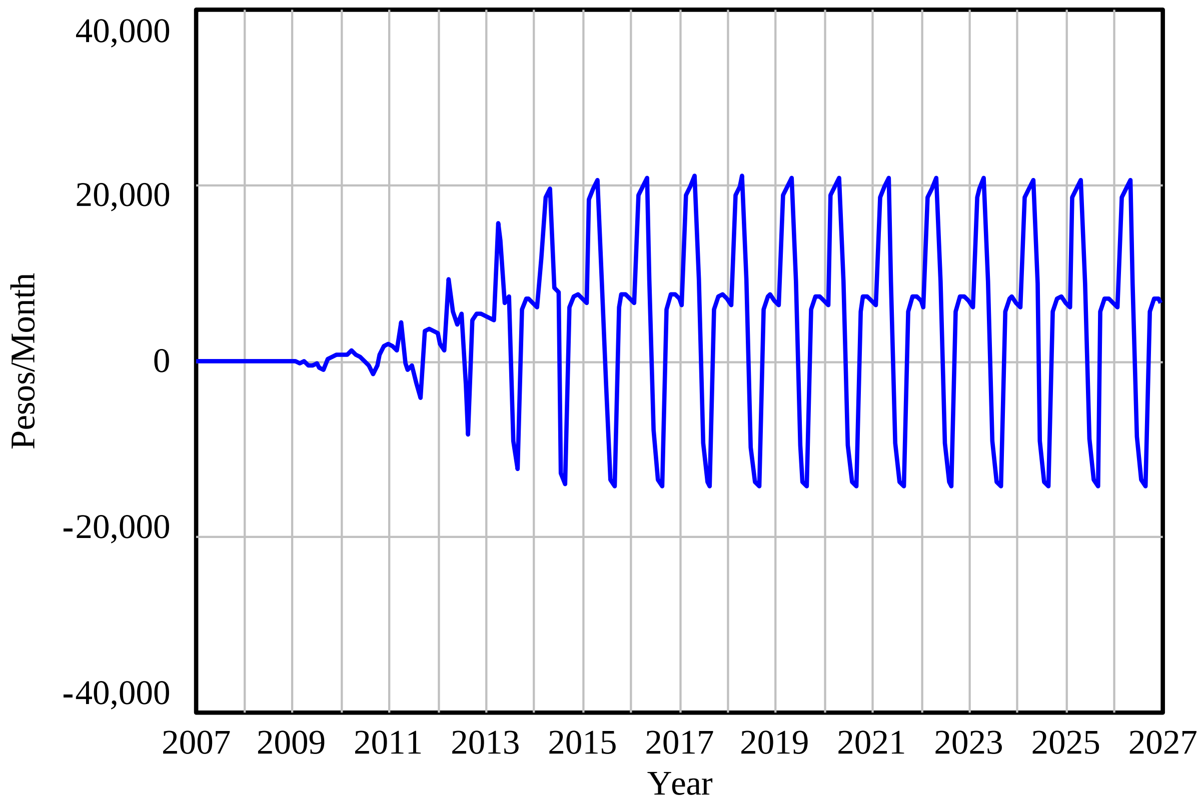

Figure 6 Monthly net incomes of the cheese cooperative in the cooperative simulation, excluding dividend payments and cooperative capacity investments.

Importantly, the cooperative incurs cash losses for slightly longer than three months from mid-May to mid-August. This occurs due to limited or absent milk production during the dry season, which exhausts inventory after a four-month cheese maturation delay and a short sales delay. Coincident with the exhausted inventory, cheese production and storage again incur costs. A similar behavioral pattern is observed in the cash balance of the cooperative, which also includes deductions due to investments in cheese processing capacity and dividend payments. However, notably, the stock of cooperative cash holdings never becomes negative during the simulation.

The cooperative's inability to meet the market demand for aged cheese at some times may be a critical limitation to success of the cooperative enterprise because cancelled orders signify opportunity losses in cheese sales income. Cooperative and producer net incomes could be improved by stabilizing milk and cheese supply throughout the year. Of the 42,700 kg total orders for cheese from 2009 to 2027, over 10,600 kg are unfulfilled. This represents a cancelled order rate of almost 25% and approximately $1.2 million pesos in lost income[3]. Future modeling work will explore approaches for mitigating these losses. Nonetheless, the cooperative simulation suggests that an aged cheese cooperative could be effective in improving farmer net incomes. Numerous additional scenarios and tests were undertaken to evaluate the market

[3] This calculation assumes an average aged cheese price of 113 pesos/kg, the approximate average price for aged cheese during the cooperative simulation.

conditions, production and processing costs and climate patterns. These scenarios pointed to the same overall conclusion.

Model Sensitivity Tests

Most parameter estimates[4] were obtained from the INIFAP-led micro-watershed development project. This information consisted of survey data, measurements and observations by INIFAP workers and their expert opinions. Because of uncertainty in these parameter values, we undertook comprehensive parameter sensitivity testing to evaluate the probability that operation of the cooperative may be infeasible (i.e., cooperative would fail financially or producer incomes would drop below historical levels). Sensitivity tests were completed for all model parameters using a Latin Hypercube sampling approach with 100 simulations. The six policy-sensitive parameters are constants related to flock makeup, cheese yield, milk production, production cost, milk consumption, and fluid milk price. Combined with the results of production and market shocks, the limited number of policy-sensitive parameters suggests that the basic idea of the cooperative may be financially feasible and likely to increase net income through Micoxtla caprine activities.

Impacts of a Market Shock

Because the production and marketing environment for the cooperative is uncertain and potentially variable, it is important to examine further the conditions under which the cooperative can succeed. One approach to this is to simulate various significant shocks and to determine their impacts on cooperative financial performance and community net incomes. For this purpose, a simulated six-month demand reduction shock is used to test robustness of the cheese cooperative to a significant temporary shock. This approach also provides insight about system resiliency to market uncertainty. A decrease of 200 kg/month (from approximately 230 kg/mo to 30 kg/mo) for six months in market demand for aged cheese is evaluated beginning in the dry season and rainy season (January and July) of 2017 during year 10 of the simulation (Figure 7). The year 2017 was chosen to evaluate cooperative response to shocks because the cooperative had become solvent.

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[4] Parameters associated with the proposed cooperative and the aged cheese market are unknown and were estimated with greater uncertainty.

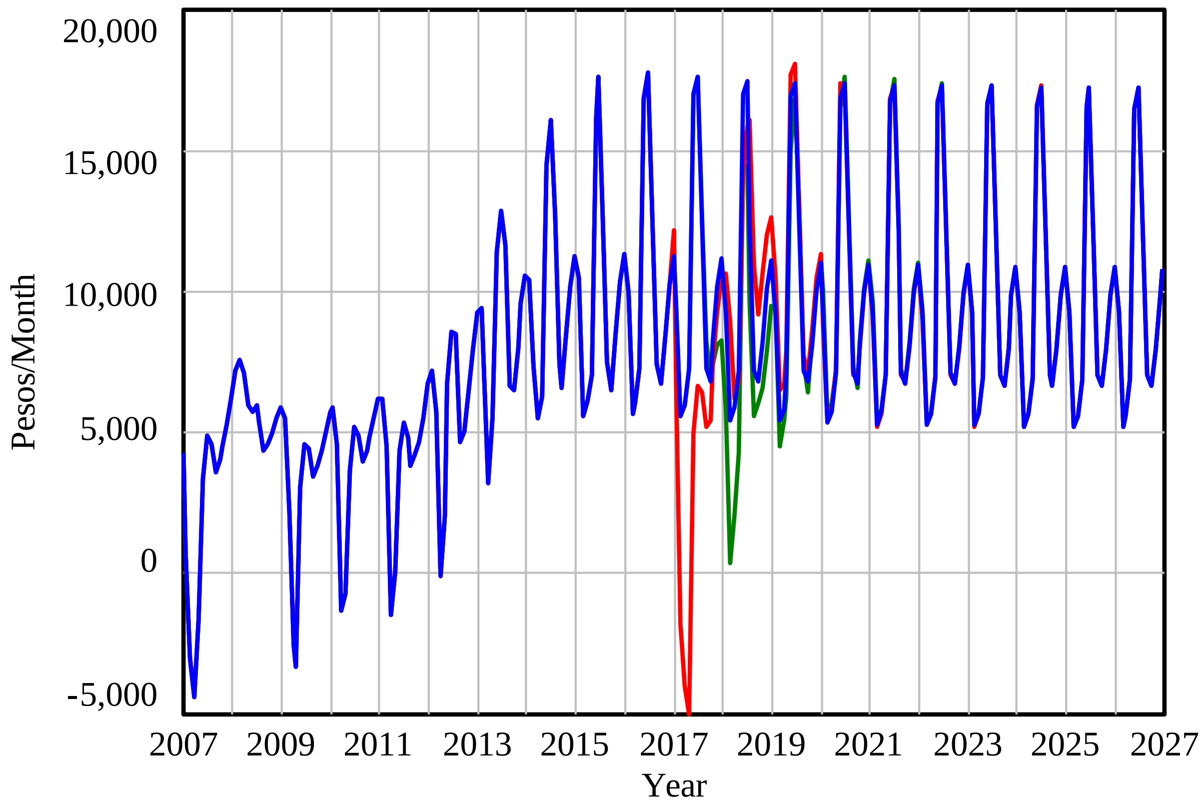

Figure 7 Monthly net incomes of aggregate community caprine operations. The cooperative simulation (blue line) is contrasted with the results of the 2017 dry (red line) and rainy season (green line) demand shocks.

Recovery from the shock requires approximately one year. The recovery periods are slightly longer than the duration of shocks because of delays in cheese production, sales, and decision making, which create inertia in the system. During recovery, monthly net income exceeds peak levels in the absence of the shock for two peaks before the pre-shock oscillating pattern is re-established. The overall effect on cumulative net income is a decline of approximately $33,000 pesos from the rainy season shock and $44,000 pesos from the dry season shock (Table 1). Losses occur from a reduction in dividend payments during and immediately after the shock. However, total reductions in cumulative net income from the shock are modest (about 2% less than without demand shock). Cooperative management policies and other income sources (e.g., sales of fluid milk, culled goats and *cabrito*) partially buffer the effects of the demand shocks by lowering capacity utilization and providing other forms of caprine income, respectively.

Table 1: Policy Analysis Simulations Results

Simulation Name	Cumulative Net Income (Millions of Pesos)	Cumulative Dividends (Millions of Pesos)	Cheese Orders Cancelled	Cooperative Solvency[5] Time
Base	0.906	0	N/A	N/A
Cooperative	1.930	0.943	10,619	2011
2017 Six-Month Dry Season Demand Shock	1.886	0.902	9,648	2011

Cooperative performance in response to a longer demand shock of one year was also evaluated (Figure 8) to assess resilience. The demand shocks beginning during periods of low seasonal net income induced large decreases in cash holdings by the cooperative. A longer demand shock suggests that in order to sustain a more severe, or prolonged, demand shock the cooperative would need to implement more conservative capacity expansion and dividend payment policies or have the ability to acquire loans during and after the shock period. The same 200 kg/mo demand shock for greater than one year causes larger negative cash balances and could bankrupt the cooperative. Economic losses for the cooperative occur because it incurs cheese storage costs from excess inventory during and after the shock period.

[5] For the purposes of this analysis, cooperative solvency is defined as the time when the cooperative is able to fulfill desired capacity investments and make dividend payments given the cooperative management structure.

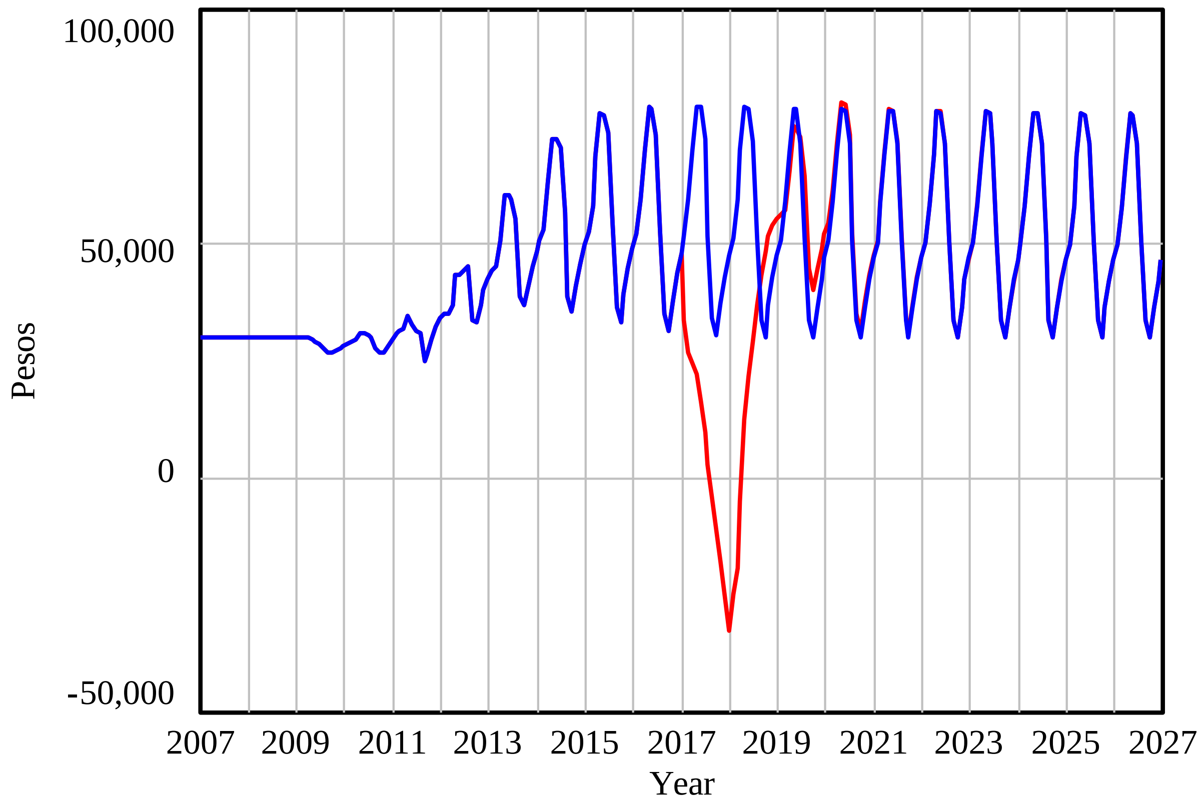

Figure 8 Cash holdings of the cheese cooperative. The cooperative simulation (blue line) contrasts the results of a 200 kg/mo decrease in market demand for a period of one year (red line). The market shock begins January (dry season) 2017.

The cooperative can survive intense and lengthy demand shocks (less than one year) if it endogenously decreases capacity utilization[6] in response to diminished consumer demand during the shock period. A negative cash balance is normally prevented under this cooperative management strategy, but it also further depresses farmer incomes. This could lead to a loss in farmer confidence in the cooperative.

An additional potential concern about the feasibility of the cooperative is the price of aged cheese. Falling prices (perhaps due to competitors also serving the Xico market) could create financial difficulty. The impact of an aged cheese price shock (Figure 9) is evaluated by simulating a $50 pesos/kg decrease in the market price of aged cheese for one year starting in the dry and rainy seasons of 2017. Market price fell from approximately $110 pesos/kg to $60 pesos/kg. The behavioral results and implications of this price shock are similar to those of the demand shock because it also directly affects net income of the cooperative.

[6] Capacity utilization decreases endogenously when cheese demand is below cooperative supply in all shock simulations.

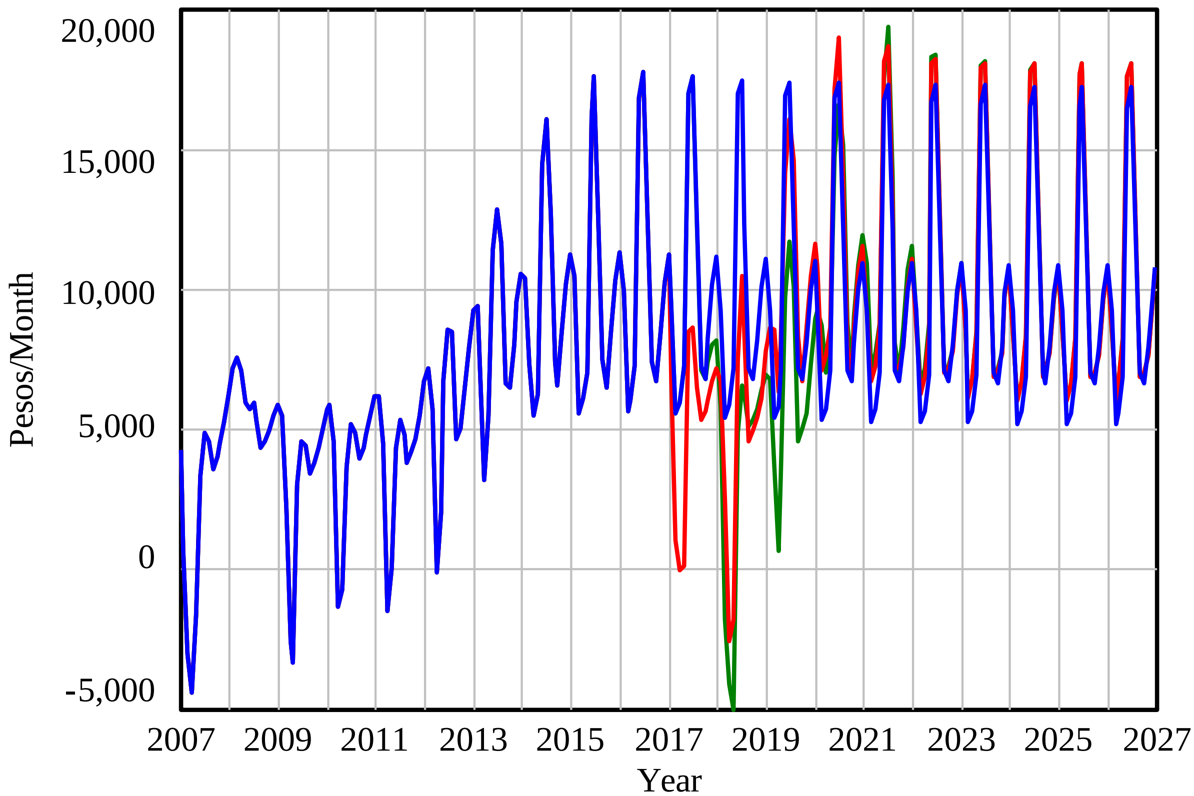

Figure 9 Monthly net incomes of aggregate community caprine operations. The cooperative simulation (blue line) is contrasted with the results of the 2017 dry season (red line) and rainy season (green line) price shocks.

5. Conclusions

Our simulation results strongly indicate that if a market exists, or could be developed, for high-value aged cheese, this activity could increase the net incomes of producer caprine operations. It could also increase the capacity of goat farmers' to buffer their incomes in times of adversity (e.g., production or market shocks) with an additional source of income from cooperative dividend payments. This is especially important during the dry season when other forms of agricultural income are low. Due to delays in cheese processing and sales, most dividend payments would be made during the dry season, which can serve to smooth incomes over time. However, our modeling analysis does not fully represent the potential financial or social benefits of cooperatives for the Micoxtla community, or others like it. As suggested by Staal et al. (1997), a value-added dairy cooperative may also reduce transactions costs for participating farmers. Although the current model does not differentiate between transactions costs for fluid milk sales in Xico and fluid milk sales to the cooperative, this could be another important motivation for participation in the cooperative. Finally, farmers hold more collective bargaining power as a collective unit in the market place than they do as individual sellers, which is another advantage of cooperative action. Production of other value-added products in rural communities could further mitigate the risks associated with agricultural livelihoods. A similar approach to the one adopted in this paper could also be applied to these products.

Notably, market demand and price shocks did not appear to create new longer-term trajectories for net income or cooperative cash flow. The system behaved resiliently to shocks of extended duration. Following recovery, the important financial variables returned to their previous oscillatory patterns. This was a result of the nonlinear biological effects and producer decisions in the model, which were sufficiently responsive to preclude resource depletion. Nonetheless, extreme conditions such as a multi-year extreme drought were not fully evaluated.

Initial investment is necessary to commence operation of the cooperative, and this would likely need to come from externally-provided development funds given the limited current financial resources within the community. We estimate that initial working capital and equipment investment costs would total less than $100,000 pesos based on observed small-scale dairy processing costs (Nicholson and Stephenson 2006). From 2009 to 2027, the cooperative would return more than $900,000 pesos in dividends paid to farmers. In addition, cooperative managers would require training in hygienic cheese processing, facilities repair and maintenance, and business management practices (e.g., accounting, customer relations, and marketing). The training program could be organized and delivered by INIFAP or other development organization. Additional risks to cooperative success include corruption, lack of farmer participation (supply limitations), market limitations, and product quality issues. An appropriate next step would be expansion of the model to include additional upstream and downstream linkages and innovations.

***Note**: Model documentation including parameter estimates and the model itself are available from the author upon request.*

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