Enhancing Year-Round Profitability for Small-Scale Ranchers: An Economic Analysis of Integrated Cattle and Mushroom Production System

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Abstract: Profitability remains elusive for many small-scale cattle farmers, as the high operational costs involved often require a larger herd to achieve a reasonable profit. This study uses key financial metrics and the Monte Carlo probabilistic simulation to evaluate the economic feasibility and viability of integrating cattle and mushroom production to enhance year-round profitability for small-scale ranchers. The study results illustrate a promising outlook for investing in the integration of cattle and mushroom production. This integrated system shows potential for generating significant returns with minimal risk over the long term. The Monte Carlo simulation indicates that combining mushroom farming with cattle farming could substantially decrease feed expenses, fertilizer costs for hay production, and overall operational expenditures, while also increasing revenue from mushroom sales.

Keywords: integrated farming; cattle production; mushroom farming; economic feasibility; sustainable agriculture; profitability; Monte Carlo simulation

1. Introduction

Farm profitability remains the foremost objective for many small-scale farmers [1–3]. Nonetheless, the economic landscape for many small-scale ranchers is challenging, characterized by fluctuating market prices, land use constraints, climate uncertainties, and escalating management and operational costs [4,5]. Unfortunately, a significant number of farmers have been forced to exit the profession due to minimal or negative profit margins [1,3]. This study aims to evaluate the economic feasibility and viability of an integrated mushroom and cattle production system (ICMPS) as a means to enhance year-round profitability for small-scale cattle ranchers in North Carolina (N.C.), United States (U.S.).

Over the past few decades, research in the field of livestock has primarily concentrated on enhancing livestock management practices to ensure environmental sustainability [6,7]. However, there has been relatively limited detailed information published regarding integrated practices that could reduce costs and offer alternative income opportunities for small-scale ranchers. The findings of the study will provide fundamental economic insights into the feasibility and viability of an integrated mushroom and cattle production system and provide a roadmap for the sustainable growth of the agricultural industry in N.C. and the U.S. as a whole.

The competition for land use between crop and animal production has underscored the need to integrate crops with livestock to enhance farming profitability and reliability [8]. Integrating cattle and mushrooms offers immediate and continuous financial benefits to ranchers. Edible mushrooms have numerous nutritional and medicinal advantages [9,10].
and require a relatively short period (one to three months) and lower capital investment to produce and sell compared to cattle farming, which takes approximately 16 months for weaned calves to mature and be sold.

Moreover, livestock feed expenses account for about 60–70% of the total cost of livestock production, with winter feed costs alone making up 20–40% of annual cow ownership expenses [11,12]. In addition to benefiting financially from the sale of harvested mushrooms, cattle ranchers can also incorporate mushroom-degraded biomass into the diet of ruminants [13]. According to Velázquez-De Lucio et al. [13], mushroom-degraded biomass can reduce the cost of livestock feeding and enhance digestibility, feed efficiency, and overall animal health. Furthermore, research indicates that integrating cattle farming with mushroom production can reduce manure management costs by utilizing manure as mushroom substrates [14,15]. Figure 1 illustrates the circular economy of the cattle and mushroom integrated production system.

![Figure 1. Circular economy of cattle and mushroom integrated farming.](image)

This study proposes utilizing corn stover, an abundant agricultural residue and waste, as a substrate for oyster mushroom production. Corn stover presents a cost-effective and economical alternative to hay for cattle feeding, particularly during the winter. However, corn stover, in its natural state, is a dormant crop residue that lacks nutrients, and its abundant carbohydrates are bound by lignin, making them inaccessible for rumen fermentation. Growing mushrooms on corn stover before feeding them to cattle allows fungal enzymes to break down lignin [16] and facilitates the secretion of health-modulating bioactive compounds such as glycopolysaccharides, lectins, and proteins into the substrate to enhance cattle health [17]. Anike et al. [18] demonstrated that oyster mushrooms (Pleurotus ostreatus) degraded corn stover and improved their nutrient and nitrogen content.

Despite the existing research and information on integrated farming systems, limited research exists on the use of corn stover in mushroom production and the subsequent treatment of spent biomass as cattle feed. In summary, the integration of cattle and mushroom production has the potential to offer a continuous supply of a nutrient-rich spent mushroom substrate as cattle feed without incurring additional costs. This integration would ensure year-round profitability for cattle farmers by generating income from mushroom sales and reducing cattle feed costs. Moreover, it would promote the health of cattle and allow for the utilization of abundant and renewable agricultural waste in the form of corn stover.
1.1. Brief Overview of the Economics of Integrated Farming Systems

An integrated farming system (IFS) is a mixed farming approach that combines crop and livestock activities in a mutually beneficial manner [19,20]. The objective is to implement a set of practices for resource development and utilization that results in significant and sustained increases in agricultural production and farm income [21]. Radhamani et al. [22] characterize the IFS as a strategy to minimize risk, enhance production and net profit, and improve the utilization of farming wastes and crop residues. Research indicates that integrated crop and livestock systems are highly productive, profitable, environmentally sustainable, and can lead to employment opportunities, particularly for small and medium-scale farmers [22–37].

An integrated farming system (IFS) offers opportunities for small and socially marginalized farmers with limited land to combine crops, animals, and other components, thereby minimizing risks and generating additional income from the same piece of land [38]. Nageswaran et al. [39] discovered that the average annual net revenue per acre of an integrated farming system is more than 2.5 times that of a conventional farming system. Channabasavanna et al. [40] developed a rice–fish–poultry system for rice-growing farmers in Karnataka, India, and found that the designed system exhibited the highest productivity, with a 26.3% increase compared to the conventional rice–rice system. Despite the numerous benefits of the IFS, some integrated systems require more money, labor, and other resources to initiate and maintain [19,20,23,41–43]. For instance, Manjunath and Itnal [27] observed that integrating dairy production with coconut through forage intercropping increased net returns nearly fivefold compared to a monocropping system, but the production cost of the integrated system also increased by fivefold. This study contributes to the advancement of food and agricultural economics by investigating the economic feasibility and viability of an integrated mushroom and cattle production system.

1.2. The Integrated Mushroom and Cattle Production System (ICMPS) Concept

Small-scale cattle farmers face the ongoing challenge of ensuring economic viability amidst seasonal changes and fluctuations in cattle feed availability. Relying on forage resources highlights the importance of strategies that optimize forage use and minimize inputs while maintaining a reasonable cost for cattle production. In the western United States, many farmers feed mature cows between 1500 to 3000 kg of hay during the winter feeding period, leading to increased production costs [44]. The cultivation of edible mushrooms has, however, garnered considerable attention in agriculture due to its economic significance and nutritional benefits. Mushroom farming could provide alternative income opportunities for small enterprises [45] and offer environmental benefits, as mushroom cultivation is considered an eco-friendly agricultural practice [46]. The Small Farms Program at Cornell University [47] estimates that a 1000-log shiitake outdoor operation established on half an acre of woodland, with an initial cost of approximately USD 4740, is expected to yield around 1040 pounds of mushrooms. This would generate an estimated gross income of about USD 12,480, equivalent to USD 24,960 per acre. Moreover, the Small Farms Program at Cornell University [47] predicts a higher profit potential for indoor growing operations, with net income ranging from USD 1 to USD 3 per square foot. This implies a potential income of USD 43,560 to USD 130,680 per acre.

Furthermore, there is a growing demand for mushrooms in the United States, leading to increased sales and expenditure on imported mushrooms. This trend is driven by consumers seeking healthier, nutritionally rich, and medicinal food options [48,49]. According to Lucier et al. [48], per capita mushroom consumption has quadrupled since 1965, with a positive correlation observed between mushroom consumption and income levels. Furthermore, traditional agricultural practices involving crops and livestock require substantial investments in land and equipment, whereas mushroom production requires relatively lower investments and can be adapted to various production environments and materials such as straw, cotton seed hulls, corn cobs, peanut shells, coffee pulp, paper, and leaves [47]. In addition to providing an alternative income stream through mushroom
production and sales, the spent mushroom substrate (SMS) can serve as feed for various animals, including fish, poultry, pigs, and cattle [50–53]. Paripuranam et al. [52] conducted an experiment using *Labeo rohita* and *Hemigrammus caudovittatus* fingerlings, feeding them a diet comprising 9% fish meal and 9% mushroom meal; 9% fish meal and 9% worm meal; or 18% fish meal. They observed that the diet containing earthworm meal led to approximately a twofold increase in growth rate compared to the fish meal diet, while the diet with mushroom meal showed a 1.2 to 1.7-fold increase. This suggests that mushroom meals can supplement fish diets, reducing feed costs [52]. In addition to reducing feed costs, supplementing cattle feed with SMS has been shown to enhance the digestibility of straw by degrading lignin and cellulose in straws [54] and improve the growth performance of cattle [55].

2. Materials and Methods

2.1. Model Construction

The study integrates the Agroecological Systems theory and the Resource-Based View (RBV) to integrate cattle and mushroom production. The Agroecological Systems theory emphasizes the interactions between components like livestock, crops, and the environment. It highlights the importance of integrating diverse components to enhance sustainability, productivity, and resilience in farming systems [56]. The Resource-Based View (RBV), on the other hand, suggests that firms should explore and utilize their resources and capabilities to achieve a competitive advantage [57]. This integration aims to optimize existing resources to establish and enhance competitive advantages, productivity, and various revenue streams. The ultimate objective is to promote a more balanced and resilient agroecosystem.

To evaluate the economic feasibility of integrating cattle and mushroom production, we used a combination of data sources and economic modeling. This involved conducting informal interviews with experts in cattle production, reviewing farm records, and incorporating published data on mushroom production costs. Data were collected from the experimental farm of North Carolina Agricultural and Technical State University (NC A&T), which spans 492 acres and is involved in livestock, horticultural, and mushroom production. The data included expected yields, inputs, and product prices for both cattle and oyster mushroom enterprises. Two economic scenarios were modeled: (1) cattle production without mushrooms (conventional system); and (2) cattle production with mushrooms (integrated system).

The cattle operation within the integrated system utilizes a medium-fattening beef production system while the mushroom operation uses an indoor cultivation system. The study adapted a pilot experiment to produce oyster mushrooms as detailed in Anike et al. [18]. This involves an indoor cultivation model using a fruiting house with environmental controls for temperature, humidity, and light, designed for year-round production. The process includes pasteurizing the corn stover-based substrate in 4.5 kg bags, inoculating the substrate with a prolific and high-yield strain of oyster mushrooms from a culture bank at a rate of 10% spawn to 90% substrate, and incubating for 30 days [18] under conditions of 70% moisture content, 15–20 °C temperature, 80–90% humidity, and minimal light. The substrate comprises 94% corn stover, 5% wheat bran, and 1% gypsum. Alternatively, cow dung can be incorporated into the corn stover-based substrate as determined by Halbwachs and Bässler [15], though it must first be composted to eliminate pathogens, creating a suitable substrate for mushroom growth. Fruiting bodies can be harvested from each bag over a one-week period, after which the bags can be incubated for an additional week before using the spent mushroom substrate as cattle feed.

The economic model posits that cattle ranchers aim to maximize their expected net returns by selecting from a predetermined set of conventional and integrated systems. This suggests that a cattle rancher can switch production systems if the current system is not yielding optimal profits. The assumptions regarding cattle ranchers’ expectations are based on average weather conditions. Production input and product prices are considered
exogenous and the expected net returns are calculated assuming constant returns within the production systems. The primary outcomes of the model are the simulated distributions of net returns from the conventional system (cattle production without mushrooms) and the integrated system (cattle and mushroom production). The decision-making process of cattle ranchers regarding production systems is framed as a problem of profit maximization, with the assumption that there are no constraints on the profits achievable by cattle ranchers.

2.2. Economic Analysis

In analyzing the economic viability of the local production of cattle and mushrooms in North Carolina, we employed the internal rate of return (IRR), benefit–cost ratio (BCR), and net present value (NPV) metrics [58]. The IRR was utilized to assess the potential profitability of investing in the cattle and mushroom production system. An investment is deemed feasible if the estimated IRR exceeds the interest rate. The BCR was employed to evaluate investment risk by comparing the total expected benefits to the total cost of implementing the integrated system. A BCR exceeding 1 generally indicates a less risky and economically sound investment. Furthermore, the NPV was employed to determine whether a cattle farmer should consider making a long-term investment in cattle and mushrooms. A positive NPV suggests that, over the long term, a cattle farmer will profit from investing in the integrated system after accounting for the time value of money, whereas a negative NPV indicates a reduction in the value of the investment.

Further, we conducted a sensitivity analysis to examine the impact of increased mortality rates in cattle production at 2% and 5%, and pest damage in mushroom production at 5% and 10%, on the profitability of the integrated system, compared to the baseline of zero mortality and zero pest damage. The Monte Carlo probabilistic simulation model was also employed to determine the probability distributions for the NPV and evaluate the potential impacts of market volatility, fluctuating input costs, and production uncertainties on the financial outcomes of integrated systems. As part of the NPV analysis, total revenues from mushroom and cattle production were estimated as the product of the average price of mushrooms or cattle and the anticipated yield. Similarly, the total production costs for mushrooms and cattle were estimated. Data from the NC A&T farm records were utilized to estimate both fixed costs (costs that remain constant regardless of the level of production each year) and variable costs (costs that fluctuate based on the level of production). Profit distributions were then estimated by subtracting the cost of production from the revenue generated by the sales of mushrooms and cattle. The economic analysis was conducted using Excel version 2302 and Rstudio version 2024.04.2+ 764 analytical software.

2.3. Statistical Analysis

The net present value (NPV), representing the present value of all future cash flows, was calculated in Excel using Equation (1). This calculation incorporated the initial investment and all future revenues and expenses over a five-year period.

\[
NPV = \sum_{t=1}^{n=5} \frac{R_t}{(1 + r)^t} - C_0
\]

where \( R_t \) is the net cash inflow during period \( t \); \( C_0 \) is the total initial investment cost; \( r \) is the discount rate; and \( t \) is the number of time period.

The internal rate of return (IRR) represents the interest rate at which the discounted cash inflows from the production system exactly match the initial investment and ongoing costs. Using Excel, we estimated the discount rate at which the NPV equals zero, as per Equation (2).

\[
0 = NPV = \sum_{t=1}^{n=5} \frac{R_t}{(1 + i)^t} - C_0
\]

where \( R_t \) is the net cash inflow during period \( t \); \( C_0 \) is the total initial investment cost; \( i \) is the internal rate of return (discount rate at which NPV = 0); and \( t \) is the number of time period.
The benefit–cost ratio (BCR), which compares the total discounted benefits of the integrated production system to total discounted costs, was estimated in Excel using Equation (3).

\[
BCR = \frac{\sum_{t=1}^{5} B_t (1+r)^t}{\sum_{t=1}^{5} C_t (1+r)^t}
\]  

(3)

where \(B_t\) represents the benefit in period \(t\); \(C_t\) represents the cost in period \(t\); \(t\) is the number of time period; and \(r\) is the discount rate.

The sensitivity analysis was performed in R using custom functions, ‘cattle_revenue_impact’ and ‘mushroom_revenue_impact’, to model the linear effects of the mortality rate and pest damage on profits. This involved multiple iterations of various mortality and pest damage scenarios to calculate the adjusted revenues and profits.

The Monte Carlo simulation was also conducted in R, utilizing functions such as ‘runif’ and ‘rnorm’ to generate distributions of random variables across 10,000 simulation iterations. Each iteration produced outcomes based on random values to estimate the average reductions in feed costs, increases in hay yield, and operational efficiency gains. Key parameters included feed cost, hay yield, operational cost, and revenue from mushroom sales. We further estimated the variability, uncertainty, and confidence intervals using the summary and quantile functions. This method provided a robust statistical foundation for assessing the potential economic and operational impacts of integrating corn stover into the cattle–mushroom production system.

3. Results

To identify the optimal choice, the model selects the production system that yields the highest net returns. Net returns are typically calculated as the difference between expected revenue and production costs. Revenue is calculated by multiplying the price of mushrooms or cattle, expressed in USD/kg, by the expected yield, measured in kg. It is important to note that our findings pertain to small cattle farms in North Carolina, United States, and should be interpreted with caution.

3.1. Estimation of Cost, Expected Yield, Revenue, and Profit for Oyster Mushroom

Table 1 presents the estimated production costs, expected yields, revenue, and profit distribution for oyster mushroom production. These estimates reflect the typical costs and yields associated with oyster mushroom production in North Carolina. To validate our estimates, we compared them to the 2022 mushroom production budgets developed by Cornell University’s extension [49].

Table 1. Annual production cost, expected yield, revenue, and profit.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost (USD)</th>
<th>Yield (kg)</th>
<th>Price (USD/kg)</th>
<th>Revenue (USD)</th>
<th>Profit (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC-LR</td>
<td>23,529.6</td>
<td>6750</td>
<td>USD 6.70</td>
<td>45,225</td>
<td>21,695.4</td>
</tr>
<tr>
<td>LC-HR</td>
<td>23,529.6</td>
<td>11,600</td>
<td>USD 13.33</td>
<td>154,628</td>
<td>131,098.4</td>
</tr>
<tr>
<td>HC-LR</td>
<td>28,108.8</td>
<td>6750</td>
<td>USD 6.70</td>
<td>45,225</td>
<td>17,116.2</td>
</tr>
<tr>
<td>HC-HR</td>
<td>28,108.8</td>
<td>11,600</td>
<td>USD 13.33</td>
<td>154,628</td>
<td>126,519.2</td>
</tr>
<tr>
<td>Average</td>
<td>25,819.2</td>
<td>9100</td>
<td>USD 10.02</td>
<td>91,182</td>
<td>65,362.8</td>
</tr>
</tbody>
</table>

Note: Analysis is based on a farm size of 0.05 acres or 2600 sf. LC = low cost of production; HC = high cost of production; LR = low revenue; HR = high revenue.

To cover a plausible range of oyster mushroom prices, we set the mushroom price between USD 6.70 and USD 13.33 per kg. Oyster mushrooms typically yield between 0.5 and 0.8 kg per bag, with an average yield of 0.65 kg per bag. Farmers can expect multiple harvests throughout the year. Small growers, operating on as little as 0.05 acres or 2600 square feet, can harvest between 13,500 and 14,500 bags, averaging 14,000 bags of
oyster mushrooms annually. Based on this, the expected average yield of oyster mushrooms from an area of 0.05 acres is estimated to be 9100 kg (0.65 kg/bag * 14,000 bags), resulting in an annual revenue ranging from USD 60,970 to USD 121,303 for prices between USD 6.70 and USD 13.33 per kg. The estimated annual cost of production ranges from USD 23,529.6 to USD 28,108.8. This includes the costs of equipment, spawns, substrate, labor, electricity, water, and rent. Our analysis indicates that mushroom production is profitable, with profit distributions ranging from USD 21,695 to USD 126,519 and an average annual profit of approximately USD 65,000 (Table 1).

3.2. Estimation of Enterprise Budget for Small Cattle Production in North Carolina

Table 2 shows the estimated production costs for a medium-fattening beef production system in North Carolina using the Black Angus breed. These estimates are indicative of the typical costs associated with small cattle production in North Carolina. The data were primarily sourced from personal communication with Mr. Aaron Snider, the Coordinator of the beef cattle unit at the NC A&T experimental farm. This information was found to be consistent with other USDA state-level enterprise budgets for cattle production.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Initial Investment</td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>150,000</td>
</tr>
<tr>
<td>Fencing</td>
<td>10,000</td>
</tr>
<tr>
<td>Facilities</td>
<td>15,000</td>
</tr>
<tr>
<td>Water Infrastructure</td>
<td>15,000</td>
</tr>
<tr>
<td>Tractor</td>
<td>12,000</td>
</tr>
<tr>
<td>Hay Equipment</td>
<td>6000</td>
</tr>
<tr>
<td>Livestock Purchase</td>
<td>62,000</td>
</tr>
<tr>
<td>Variable Operation</td>
<td></td>
</tr>
<tr>
<td>Property Taxes and Insurance</td>
<td>1000</td>
</tr>
<tr>
<td>Feed Costs</td>
<td>12,000</td>
</tr>
<tr>
<td>Grass Seeds</td>
<td>1400</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>5000</td>
</tr>
<tr>
<td>Hired Labor</td>
<td>39,000</td>
</tr>
<tr>
<td>Farmer’s Labor</td>
<td>10,950</td>
</tr>
<tr>
<td>Veterinary Care</td>
<td>250</td>
</tr>
<tr>
<td>Maintenance</td>
<td>2500</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>1000</td>
</tr>
<tr>
<td>Total</td>
<td>343,100</td>
</tr>
</tbody>
</table>

Cattle production demands significant capital investment, particularly in land, fencing, facilities, water infrastructure, and other essential assets. In North Carolina, an average of 30 acres is required to support 30 cows, with land costs averaging around USD 5000 per acre. To initiate a small-scale operation, one would need a bull and approximately 30 pregnant cows. A semi-good-quality bull is estimated to cost around USD 2000 while acquiring 30 pregnant cows would entail an additional investment of approximately USD 2000 per cow (e.g., Black Angus breed). Fencing, essential for cattle farming, may incur costs of roughly USD 6000, in addition to USD 4000 for labor expenses during installation. Annual expenses for facilities to house and manage the cattle, including winter heating, are estimated at approximately USD 15,000. Investing in water infrastructure, which encompasses piping, well installation, and a water station, may require an additional USD 15,000. For farm operations, a tractor for various tasks may entail an investment of approximately USD 12,000, while hay equipment could cost around USD 6000. Property taxes and insurance, totaling an average of USD 1000 per year, should also be considered, although certain agricultural exemptions may apply.
Cattle feed is a recurring expense for cattle farmers. In North Carolina, some ranchers opt to graze their cattle on pastures from April 1st to November 1st. During this period, rotational grazing is commonly employed to minimize the need for supplemental feed. However, from December 2nd to March 31st, when pasture grazing is limited due to winter conditions, cattle must be provided with hay. The cost of hay round bales is typically USD 60 each, and for a herd of 30 cows, approximately 200 hay round bales will be required over the four-month winter period. In addition to these costs, there are other essential expenses to consider. This includes purchasing grass seeds for summer and winter grazing, which typically costs about USD 700 per ton for each variety. Weep grass is typically planted in winter and spring as it can withstand frost, while sorghum is used for summer and fall, enabling year-round grazing or haymaking. Furthermore, the cost of fertilizer, which is essential for maintaining pasture health, is estimated at USD 5000 per year.

Labor costs are a substantial and variable expense in cattle farming. On average, a laborer works approximately 10 h daily for 260 days a year, earning USD 15 per hour. Additionally, the cattle farmer typically allocates 15 h a day for personal labor but pays themselves a modest USD 2 an hour, or often does not pay for their time on the farm. Another significant expense is veterinary care, which includes supplements, deworming, vaccinations, and overall healthcare for the cattle. This can amount to approximately USD 200 to USD 300 per cow per year. Additionally, maintenance costs for the cattle farm, including ongoing repairs and upkeep, typically range from USD 2000 to USD 3000 annually. Fuel costs for a tractor are around USD 1000 per year.

Achieving financial sustainability can be particularly challenging for small-scale farmers, especially those with smaller herds given the relatively low revenue compared to the cost of production. For instance, selling 26 calves annually, each weighing approximately 550 pounds, at an estimated price of USD 1000 per calf, results in a revenue of around USD 26,000. Additionally, about four cull cows, each weighing an average of 1300 pounds, are removed from the breeding herd annually and sold at an average price of USD 1300 each, contributing an additional USD 5200 to the revenue.

3.3. Expected Net Returns of Integrated Cattle and Mushroom System

Table 3 presents profit estimates for the conventional system (i.e., cattle production without mushrooms) and the integrated system (cattle and mushrooms), using the variable operational cost estimates outlined in Table 2. An experimental trial conducted at the NC A&T farm’s cattle unit suggested that converting spent mushroom substrate to cattle feed could potentially reduce feed costs by 30% (Personal Communications: Dr. Anele, Associate Professor of Animal Science and Mr. Aaron Snider, Coordinator of the beef cattle unit—NC A&T). Therefore, cattle farmers utilizing spent corn stover mushroom substrates would experience reduced annual feed costs of USD 8400 and variable operational costs of USD 69,500, compared to USD 12,000 in feed costs and USD 73,000 in operational costs for conventional cattle ranchers. Table 3 indicates that small-scale ranchers are more likely to generate positive net returns (USD 27,062.80) annually if they integrate their cattle operation with mushroom production, as opposed to incurring a loss of USD 41,900 if they were solely producing cattle.

Table 3. Expected net returns from conventional and integrated systems.

<table>
<thead>
<tr>
<th>Production System</th>
<th>Cost</th>
<th>Revenue</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle only (conventional)</td>
<td>73,100</td>
<td>31,200</td>
<td>−41,900</td>
</tr>
<tr>
<td>Oyster mushroom only</td>
<td>25,819.2</td>
<td>91,182</td>
<td>65,362.8</td>
</tr>
<tr>
<td>Integrated cattle and mushroom</td>
<td>95,319.2</td>
<td>122,382</td>
<td>27,062.8</td>
</tr>
</tbody>
</table>

Note: Oyster mushroom estimates are derived from the average values presented in Table 1.
3.4. Five-Year Cash Flow and Net Present Value (NPV) Analysis for the Integrated System

Table 4 presents a 5-year cash flow and NPV projections based on an initial investment of USD 95,319.20 (refer to Table 3) and a federal discount rate of 5% at the time of the study. We assume that business conditions remain relatively stable, with expenses and revenue gradually increasing over the years. Cash flow demonstrates a business’s ability to operate effectively by illustrating the inflow and outflow of cash within the business, while NPV helps determine whether a cattle farmer should consider making a long-term investment in integrated cattle and mushroom production.

Table 4. Five-year cash flow and net present value projection for integrated system.

<table>
<thead>
<tr>
<th>Year</th>
<th>Revenue</th>
<th>Expense</th>
<th>Cash Flow</th>
<th>Net Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>−95,319.20</td>
<td>−95,319.20</td>
<td>−95,319.20</td>
<td>−95,319.20</td>
</tr>
<tr>
<td>1</td>
<td>122,382.00</td>
<td>95,319.20</td>
<td>27,062.80</td>
<td>25,774.10</td>
</tr>
<tr>
<td>2</td>
<td>126,000.00</td>
<td>100,000.00</td>
<td>26,000.00</td>
<td>23,582.77</td>
</tr>
<tr>
<td>3</td>
<td>135,000.00</td>
<td>105,000.00</td>
<td>30,000.00</td>
<td>25,915.13</td>
</tr>
<tr>
<td>4</td>
<td>144,000.00</td>
<td>110,000.00</td>
<td>34,000.00</td>
<td>27,971.88</td>
</tr>
<tr>
<td>5</td>
<td>153,000.00</td>
<td>115,000.00</td>
<td>38,000.00</td>
<td>29,773.99</td>
</tr>
<tr>
<td>Total</td>
<td>579,062.80</td>
<td>525,319.20</td>
<td>59,243.60</td>
<td>37,698.67</td>
</tr>
</tbody>
</table>

Note: Net present value = (cash flow/(1 + discount rate)^t).

Table 4 indicates a positive projected cash flow over the 5 years. A positive cash flow indicates that the farmer operating the integrated cattle and mushroom system is likely to receive more money than is being disbursed during the 5 years. The 5-year NPV value is positive and indicates that, in the long term, a cattle farmer will make money from investing in the integrated system after accounting for the time value of money.

We also calculated the benefit–cost ratio (BCR) and the internal rate of return (IRR), which is the discount rate at which the NPV equals zero. The estimated IRR was 17%. Since the estimated IRR of 17% exceeds the federal discount rate of 5%, it implies that the cattle and mushroom production system is a viable investment for small-scale ranchers. The benefit–cost ratio (BCR) was calculated at 1.39, suggesting that a dollar increase in production cost would lead to more than a dollar increase in revenue. This implies that the integrated cattle and mushroom system is a less risky and economically viable investment.

3.5. Sensitivity Analysis

Table 5 presents the outcomes of the sensitivity analysis examining the impact of mortality in cattle production and pest damage in mushroom production on the profitability of the integrated system. Regarding cattle production, the analysis explored scenarios with increased mortality rates of 2% and 5%, compared to the baseline of zero mortality rate. For mushroom production, potential reductions in mushroom yield due to pest damage were considered at 5% and 10%, compared to the baseline of zero pest damage. The results demonstrate that both increased mortality in cattle production and pest damage in mushroom production led to the reduced profitability of the integrated system compared to the baseline. For example, a 5% mortality rate in cattle production combined with a 10% pest damage in mushroom yield could result in a 39.5% decrease in the overall profitability of the integrated system compared to the baseline.
Table 5. Sensitivity analysis of the integrated system to mortality and pest damage.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Mortality Increase</th>
<th>Pest Damage</th>
<th>Adjusted Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0%</td>
<td>0%</td>
<td>USD 27,062.80</td>
</tr>
<tr>
<td>Mortality 2%</td>
<td>2%</td>
<td>0%</td>
<td>USD 26,438.80</td>
</tr>
<tr>
<td>Mortality 5%</td>
<td>5%</td>
<td>0%</td>
<td>USD 25,502.80</td>
</tr>
<tr>
<td>Pest Damage 5%</td>
<td>0%</td>
<td>5%</td>
<td>USD 22,503.70</td>
</tr>
<tr>
<td>Pest Damage 10%</td>
<td>0%</td>
<td>10%</td>
<td>USD 17,944.60</td>
</tr>
<tr>
<td>Mortality 2% + Pest Damage 5%</td>
<td>2%</td>
<td>5%</td>
<td>USD 21,879.70</td>
</tr>
<tr>
<td>Mortality 5% + Pest Damage 5%</td>
<td>5%</td>
<td>5%</td>
<td>USD 20,943.70</td>
</tr>
<tr>
<td>Mortality 2% + Pest Damage 10%</td>
<td>2%</td>
<td>10%</td>
<td>USD 17,320.60</td>
</tr>
<tr>
<td>Mortality 5% + Pest Damage 10%</td>
<td>5%</td>
<td>10%</td>
<td>USD 16,384.60</td>
</tr>
</tbody>
</table>

3.6. Monte Carlo Simulation Outcomes

As previously mentioned, the integration of corn stover as input for mushroom and cattle feed in the farming model illustrates its potential to reduce feed costs, enhance compost quality for hay production, and positively affect operational efficiency. The simulation results suggest that incorporating corn stover as a mushroom substrate could lead to a 25% reduction in annual feed costs, with some trials achieving up to a 40% reduction on average. Corn stover contributes to about 15% of this reduction in feed costs. Furthermore, using the spent mushroom substrate (SMS) as part of the cattle feed can result in additional benefits. The SMS can also be utilized as compost fertilizer for hay production, potentially reducing fertilizer costs. Simulation data indicate that about 15% of trials show a 20% increase in hay yield when using a SMS as fertilizer, with corn stover contributing approximately 10% to this improvement. Additionally, incorporating corn stover into the system could lead to efficiency gains, with approximately 10% of simulation trials demonstrating a 7% reduction in operational costs. The simulations also predict an average additional annual revenue of USD 7500 from mushroom sales when corn stover is used as a substrate for mushroom production.

4. Discussion

The study presents several noteworthy findings. Firstly, mushroom production is profitable. We examined profitability under four different scenarios (Table 1): (1) low cost and low revenue, (2) low cost and high revenue, (3) high cost and low revenue, and (4) high cost and high revenue. All scenarios indicated a positive net return, suggesting that mushroom production could potentially provide alternative income opportunities. This aligns with the findings of Chand and Singh [45], Cornell Small Farms [47], Gupta et al. [59], and Vargas et al. [60]. Secondly, cattle production requires significant capital investment (Table 2), and achieving financial sustainability can be particularly challenging for small-scale farmers [61]. Thirdly, our study finds that small-scale ranchers are likely to incur losses when focusing solely on cattle production. However, integrating mushroom production into cattle operations provides small-scale ranchers the opportunity to generate positive net revenue (Table 3). For instance, combining cattle production with mushroom cultivation can result in an excess net revenue of approximately USD 27,000, compared to a loss of around USD 41,000 when only producing cattle. This finding aligns with studies indicating that integrating crop and livestock activities can minimize risk, enhance production, and significantly increase net farm income from the same piece of land [19–40,62,63].

Our results also show that the increased net revenue from the integrated cattle and mushroom system arises from both higher revenues from mushroom sales and reduced cattle feed costs through the use of a spent mushroom substrate (SMS) as feed. Converting the SMS to cattle feed could potentially reduce feed costs by 25–30%. Additionally, a Monte Carlo probabilistic simulation analysis on optimizing financial outcomes of integrated systems suggests that incorporating corn stover as a substrate for mushroom production and cattle feed could lead to a higher reduction in annual feed costs. This finding is con-
sistent with Velázquez-De Lucio et al. [13], Paripuranam et al. [52], and Baptista et al. [64], who indicate that integrating a SMS in animal feed can reduce livestock feeding costs and improve overall animal health. For example, Paripuranam et al. [52] observed that feeding *Labeo rohita* and *Hemigrammus caudovittatus* fingerlings with a SMS led to increased growth rates and reduced feed costs.

Fourthly, we conducted a five-year net present value (NPV) analysis (Table 4), which indicates that a small-scale rancher is more likely to generate profit from an integrated cattle and mushroom system in the long run compared to solely cattle production. The estimated internal rate of return (IRR) and benefit–cost ratio (BCR) also suggest that the integrated cattle and mushroom system is a less risky and economically viable investment. While the NPV, BCR, and IRR suggest that investing in integrated cattle and mushroom farming is financially and economically viable, it is crucial to consider potential impacts on expected returns and profitability. Factors such as market fluctuations, operational risks, and unforeseen challenges should be factored into the decision-making process to ensure a comprehensive evaluation of the project’s viability [65,66].

Fifth, we conducted a sensitivity analysis to account for the impact of unforeseen factors on the perceived profitability of the cattle and mushroom integrated system. Specifically, we examined the effects of mortality rates in cattle production and pest damage in mushroom production on profitability (Table 5). We found that increased mortality rates in cattle production and pest damage in mushroom yield could lead to decreased profitability of the integrated system. Persistent mortality and pest damage could potentially undermine sustained profitability targets. These findings emphasize the significance of effectively managing both cattle mortality and pest damage in mushroom production to achieve optimal financial viability for the integrated system.

5. Conclusions

The study examined the economic feasibility and viability of integrating cattle and mushroom production systems using key financial metrics and the Monte Carlo probabilistic simulation. The analysis revealed several significant findings. The calculated financial and economic indices indicate a favorable outlook for investing in the integration of cattle and mushroom production, showing potential for generating substantial returns with minimal risk over the long term. The supplementary income from mushroom sales is particularly valuable for diversifying the revenue streams of small ranchers, providing a year-round source of income, and reducing income volatility, thus promoting financial stability. Integrating mushroom cultivation into cattle farming presents an attractive model for sustainable and economically viable agricultural practices.

The Monte Carlo simulation suggests that combining cattle farming with mushroom farming could lead to notable reductions in feed expenses, fertilizer costs for hay production, and overall operational expenditures, while also enhancing the overall health of the farming ecosystem and generating additional revenue from mushroom sales. Furthermore, a sensitivity analysis was performed to investigate the impact of the mortality rate in cattle production and pest damage in mushroom production on the economic performance of the integrated system. The analysis showed that although the integrated system offers promising economic benefits, its profitability is sensitive to these factors. Therefore, implementing effective management strategies to mitigate cattle mortality and minimize mushroom pest damage is essential for maintaining the financial viability and sustainability of the system.

Our study faced several limitations. Initially, our goal was to engage small cattle farmers in learning mushroom cultivation, providing them with mushroom fruiting houses, and training them to manage mushroom production alongside their cattle operations. This approach would have enabled the farmers to harvest and sell mushrooms regularly, generating additional income, while using spent mushroom waste as cattle feed. We recruited three small cattle farmers to participate in this experiment, and they were enthusiastic about the study. However, our plan to import mushroom fruiting houses from China was disrupted by the tariff conflict between the United States and China, rendering the plan
unfeasible. Subsequently, we explored sourcing alternative fruiting chambers locally from major mushroom producers, but progress was impeded by delays caused by the COVID-19 pandemic. As a result, we had to conduct the integrated experiment using the cattle unit at the NC A&T University experimental farm instead of with the recruited small cattle farmers. Despite these challenges, our results can serve as valuable reference information and a foundation for engaging small cattle farmers in North Carolina to adopt integrated cattle and mushroom systems.

Future research will focus on replicating the study with operational small-scale cattle farmers in North Carolina to evaluate the practicality of the cattle and mushroom integration system. Presently, there are very few, if any, studies on the economic feasibility of this integrated system. We encourage the replication and scalability of the integrated system in other regions of the U.S. and worldwide for comparison purposes. A broader comparison will strengthen the generalization of our findings and enhance the wider application of this integrated farming model.

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