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Elevating sericulture: Achieving higher yields and profits through best practices and technology

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Abstract

The Don Mariano Marcos Memorial State University Sericulture Research and Development Institute (DMMMSU-SRDI) in Bacnotan, La Union, Philippines, advocates the application of optimal sericulture techniques at extension sites to boost the income of seri-farmers, particularly those from marginal sectors. A prime example is the Sericulture Demonstration Project Farm (Seri-Farm) in Barangay Lioac Sur, Naguilian, La Union, which has successfully operated for over a decade (2011–2022) and remains active today. The farm serves as a dynamic showcase of innovative sericulture technologies, promoting sustainable agriculture, rural livelihood improvement, and economic development. Seri-farmers diversified their activities, engaging in grain and vegetable farming, animal husbandry, sugarcane cultivation, and vinegar/winemaking, with sericulture as a complementary endeavor. The initiative provided employment opportunities for out-of-school youth and community workers while catering to both domestic and international silk markets. The farm's medium-textured soil, high nutrient content, and favorable weather during most rearing seasons supported high-value cocoon production, though larval performance was affected in 2017 by disease and climate change. Over its 11-year span, the Seri-Farm achieved significant results, completing 31 rearing cycles and producing 392.7 kg of fresh cocoons, generating a total income of PhP94,935.00. Additionally, allied products such as cuttings, saplings, seeds, novelty items, fruit beverages, vinegar, wine, and compost contributed PhP176,215.00, underscoring the economic potential of integrated sericulture farming systems.

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Introduction

Sericulture involves mulberry cultivation, silkworm breeding, and post-cocoon activities to produce silk yarn. Sericulture helps anti-poverty efforts by providing productive work, economic development, and quality of life to rural people and preventing them from moving to cities. Several developing nations, including China, India, Brazil, Thailand, Vietnam, Indonesia, Egypt, Iran, Sri Lanka, Philippines, Bangladesh, Nepal, Myanmar, Turkey, Papua New Guinea, Mexico, Uzbekistan, and some African and Latin American countries, have adopted sericulture to employ rural people. Besides silk, sericulture produces various byproducts, Thangavelu (2002) noted.

Mulberry fruits are rich in minerals and vitamins, while their roots, bark, and leaves are used in Ayurveda, the traditional system of medicine that originated in India over 3,000 years ago, as well as in herbal remedies. Some varieties of mulberry trees produce termite-resistant wood, which is used to make sports equipment, toys, and other items. After silkworm feeding, dried mulberry branches are repurposed as fuel in rural areas. Mulberry leaves also serve as cattle feed. The trees are commonly planted as avenue trees or along embankments to prevent soil erosion. Silkworm pupae are rich in oil, which is utilized in cosmetics, while the pupal cake serves as a protein source for poultry and aquaculture. In some tribes, Eri pupae are consumed as a nutritious protein source. Additionally, silkworm litter is used to generate biogas for cooking in rural communities (Thangavelu, 2002).

Sericulture not only provides silk for fashionable clothing, but it also provides several very useful by-products to human society. Thus, sericulture development can improve rural living standards in developing countries. The Philippines is also promoting sericulture as an agro-based industry due to its economic and ecological potential. Due to its year-round mulberry growing climate, underutilized land, and labor, the Philippines' mulberry production is profitable; it improves ecological balance as well besides providing economic benefits.

The country faced prolonged shortages in food, vegetables, and clothing, which led to a high demand for silk and silk-related products, ultimately challenging the silk industry.

A significant mismatch in supply and demand arose, particularly for uniforms for 1.4 million government workers and other clients. This situation underscores the expansion of agro-based industries with export potential and aligns with the national goal of industrializing the Philippines by 2020. The Ilocos Region, located in the northern Philippines, is well-suited for sericulture, with its underutilized land and a population of hardworking, farm-oriented Ilocanos. Demand for silk cocoons, fibers, and fabric has been growing in recent years. It is clear that commercial silkworm cocoon production must be scaled up, which can be achieved by expanding mulberry farming to support increased silkworm rearing and higher cocoon production.

Strategically located in La Union, Ilocos Region, the sericulture projects tested optimal sericulture technologies to promote sustainable cocoon production. However, the lack of effective management practices for successful sericulture led to lower farm productivity and profitability (Caccam and Mendoza, 2010). This challenge is especially prevalent when new sericulture farmers settle in marginal areas, where soils often contain minimal organic matter (<2.0%), phosphorus (<20 ppm), and exchangeable potassium (<390 ppm) (Apilado *et al.*, 2021). Many areas are rain-fed, have limited water supply, and suffer from low cocoon production due to silkworm pests, diseases, free-roaming animals, and poisoning. Producers in developing sericulture locations also face limited access to resources, facilities, and training (DMMMSU-SRDI Extension Reports, 2021; Caccam, 2022).

To encourage farmer participation in the sericulture initiative in Lioac Sur, Naguilian, La

Union, information drives and orientation sessions were conducted. Site visits and dialogues helped clarify the implementation mechanics outlined in a memorandum of agreement. The farmers provided land, labor, and capital, while the Institute supplied appropriate technologies and support services, including training and cost-effective input materials. The project also offered a soft loan for mulberry planting, sterilized silkworm rearing, and the production of both food and non-food products. Successful project implementation was ensured through effective monitoring and evaluation by the Institute and the University, using process documentation, record-keeping, and SWOT analysis based on observations and key informant surveys.

The project focused on showcasing sericulture best practices, with goals to: (a) demonstrate and document the technologies for mulberry leaf production, silkworm rearing, and the manufacturing of food and non-food products; (b) produce high-quality silkworm cocoons; and (c) improve farmers' livelihoods by providing additional income and employment opportunities for their families and communities.

Materials and methods

Historical background of Naguilian, La Union

Naguilian, a first-class municipality in La Union, Philippines, is home to 52,189 residents as of the 2020 census. Located 40 kilometers from Baguio City via Naguilian Road, it spans 37 barangays at coordinates 16°31'56"N, 120°23'45"E. The town's layout features linearly arranged buildings along barangay roads, while its fertile valleys support the cultivation of rice, corn, tobacco, sugarcane, vegetables, and other crops. Renowned for its agricultural productivity, Naguilian is also a key producer of *basi,* vinegar, and other local products. Rich in natural resources, the municipality boasts extensive forested areas, contributing to its designation as a watershed, underscoring its ecological and agricultural significance.

Naguilian, the birthplace of the original *basi,* has been producing this traditional sugarcane wine since World War II. With support from the local government, the *basi* industry has been revitalized and is now a significant source of income for the province. Renowned for its unmatched sweetness and flavor, Naguilian's vinegar and *basi* are crafted from sugarcane grown in its fertile soil. In addition, the town's thriving woodcraft and bamboo craft industries highlight its artisanal heritage, with woodcrafts, leather goods, and knitted garments and exquisite silver products available in the town center.

Visitors can explore the Naguilian Agricultural Complex to witness the basi-making process and enjoy wine tasting. The annual Basi Festival, held from May 1 to 8, coincides with the St. Augustine Pastoral Fiesta on May 5, offering a vibrant celebration of the town's culture and traditions. For nature enthusiasts, San Antonio Mini Rice Terraces, Tuddingan Falls, and Sangbay Falls provide scenic hiking and relaxation spots. Meanwhile, St. Augustine Church and the Mary Consolatrix Monastery offer serene spaces for contemplation and spiritual reflection.

Project site description and selection

The Lioac Sur - Naguilian Sericulture Project aimed to improve the socio-economic status of local residents by demonstrating the viability of sericulture as a sustainable agricultural enterprise. The initiative focused on optimizing underutilized upland and rolling terrains to boost agricultural productivity and sustainability. Additionally, it addressed the growing demand for cocoons by filature facilities, supporting the production of silk and related goods for both domestic and international markets.

The project was spearheaded by SRDI in partnership with local government units, pilot barangays, and farmer cooperators (FCs) to develop sericulture commodities. Implementation began with the selection and validation of production sites, followed by farmer training and seminar workshops.

The project encompassed five key components: a) Sapling Production, cultivation of high-quality mulberry saplings; b) Mulberry Plantation Establishment, development of plantations to provide sustainable feed for silkworms; c) Construction of Rearing Houses, setting up facilities for efficient silkworm rearing; d) Silkworm Rearing, cultivating silkworms for cocoon production; and e) Marketing, facilitating the sale of cocoons and allied products. Monitoring and evaluation were integral to the project, ensuring continuous improvement and the achievement of its objectives.

Selection criteria

The following criteria were considered in the selection of the project site:

1. Interest and dedication. The Institute could be contacted by interested parties through any SRDI extension agent. Farmer applicants were required to demonstrate a strong commitment to the initiative.
2. Suitability of the area for sericulture. The proposed area was inspected and validated by technical experts to determine its suitability for producing an adequate quantity of mulberry leaves.
3. Free from pollution. Mulberry plantations were required to be kept free from smoke emissions and pesticide sprays.
4. Available farm tools and machines. Farmer demonstrators were required to have all the necessary implements to ensure proper application of Package of Technology (POT).
5. Abundant irrigation water. The plantation had to be situated in close proximity to the water source to ensure an uninterrupted supply of foliage.
6. Ready workforce**.** A labor force was essential to fully capitalize on the benefits of farm operations; therefore, the farm demonstrator had to consistently remain prepared.
7. Willingness to share supplemental funds for logistics and other expense items. The farmer demonstrator was required to supplement the project budget due to insufficient funding.
8. Willingness to follow the POT. The success of this endeavor was contingent upon the correct implementation of the POTs.

Extension approaches

Orientation seminar

Before the project was implemented, farmer cooperators attended an orientation seminar to gain knowledge about the Institute's sericulture programs and practices. A tour of the Institute was conducted, allowing participants to observe the sericulture facilities and activities. The feasibility of mulberry and cocoon production was assessed at the project sites of interested producers. Ultimately, qualified participants signed a Memorandum of Agreement (MOA) outlining the duties and obligations of each party.

Package of technologies introduced and adopted

The best practices developed and packaged by SRDI were introduced to and adopted by farmer demonstrators. Any innovations that enhanced production outputs were documented and recorded.

A. Sapling production technology

Farmers were encouraged to establish their own nurseries to reduce investment costs for planting supplies and to serve as income-generating enterprises. Additionally, this initiative supported proper waste management and promoted ecological balance.

B. Mulberry plantation establishment and leaf production

The area was carefully prepared, and the saplings were immersed in a fungicide solution for at least 10 minutes before being planted in the field. Saplings were transplanted using a double-row planting strategy, with a spacing of 1.5 meters between double rows and 0.5 meters between rows and hills. Planting was carried out using building pits and dibbling. The soil was then pushed down around the base of the saplings to retain moisture. Light watering was applied immediately after planting and repeated a week later as needed.

Fertilizer was applied according to the recommendations of the soil analysis, and leaf age and size were considered during silkworm rearing.

Late-stage worms were fed a combination of harvested leaves and branch feeding.

C. Rearing house/culture house

The design and dimensions of the rearing house were tailored to the size of the mulberry plantation, while the materials used were determined by the farmers' financial capacity, the availability of local resources, and loans provided by governmental and non-governmental organizations.

D. Silkworm rearing

Silkworms in their fourth instar, second feeding stage, were supplied and delivered to the seri-farmer. A combination of plucked leaves and branch feeding was used to nourish the silkworms until they reached the fifth instar stage. The prescribed feeding schedule (5:00 AM, 10:00 AM, and 7:00 PM) was followed, with minor adjustments that included an additional meal at 9:00–10:00 PM.

Three trial rearings were conducted under the careful observation and supervision of the Training Officer, Project-in-Charge, and Subject Matter Specialist as part of the training program for the farmer-cooperators (Almojuela *et al.*, 2019).

Swot analysis of the project

The success of any endeavor can be attributed to a multitude of factors, which are often explored through tools like SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats). Each of these elements helps identify critical factors that can influence the outcomes of a project or initiative.

Strength

The farm's location was optimal, facilitating efficient management and production due to its proximity to the residential house. Mulberry plantations and the rearing house were situated close to the farmer's residence, ensuring ease of mobilization and accessibility. SRDI provided rearing facilities and associated equipment, including rearing racks, trays, cocooning frames, cleaning nets, and bed nets, as loans.

A supportive family was readily available to assist with silkworm rearing and production. The accessibility of the site and the well-developed road network streamlined the marketing process for the produce. SRDI served as the exclusive marketplace for all cocoons produced.

Weakness

The limited growth of mulberry and leaf yield, particularly during the dry season due to water scarcity, impacted the quantity of cocoon production during silkworm rearing. The health and disease-free status of the silkworm larvae influenced the quantity and quality of cocoons produced, as measured by the yield per box during each rearing season.

Opportunities

Despite challenging rearing conditions, the farmer was motivated to continue sericulture farming due to the high price of cocoons and the ready market. The farmer received training in various aspects of sericulture, including the production of novelty items and silk-related products.

Threats

The limited water availability during the dry season hindered mulberry growth and leaf production, restricting the number of silkworm rearing cycles. Additionally, the prevalence of diseases and pests during the rainy season negatively impacted silkworm health and cocoon production. The lack of available land for mulberry plantation expansion further limited the scope of the sericulture operation.

Intervention strategies

Intervention measures in sericulture were implemented to improve both mulberry crop yield and silkworm performance at the farmers' locations, as outlined in Table 1. These measures included the introduction of best agricultural practices for mulberry cultivation, such as optimal planting techniques, soil conditioning, and the use of appropriate fertilizers based on soil analysis. Additionally, specific strategies were employed to ensure the health and growth of silkworms, including

the provision of high-quality leaves for feeding, adherence to a structured feeding schedule, and the introduction of pest control methods. These interventions were aimed at maximizing productivity and ensuring the sustainability of sericulture operations at the farmer level.

Table 1. Intervention strategies of sericulture in Lioac Sur, Naguilian, La Union, Philippines

Problems/Issues	R & D	Support services	Policy and institutional support
Availability of healthy worms		Coordination with the silkworm larvae production in-charge	Improvement of laboratory facilities and skills of labourers performing laboratory examinations of silkworm larvae
Low mulberry leaf yield during summer months		Limited SW larvae reared Utilization of the fruits for fruits juices, wine and vinegar making	
Low cocoon quality	Production of better Quality silkworm breed		Improvement of the grainage facilities
Rising cost of inputs		Use locally available materials	
Pricing of cocoons		Review of economics	Increasing the price of good and bad cocoons

Results and discussion

The Lioac Sur sericulture site

Barangay Lioac Sur was a tranquil and progressive barangay in Naguilian, La Union, Philippines, located approximately 1.5 kilometers north of the national highway. The sericulture demonstration farm was developed across several agricultural areas that were easily accessible from the municipal road.

A. The farmers

Mr. Ludovico L. Pulmano, the first farmer-cooperator at Lioac Serifarms, was a 93-year-old farmer and a *Basi* magnate. He was married and the father of 10 children. He was involved in the production of *basi* and vinegar from rice, maize, vegetables, and sugarcane. Upon his passing, his 62-year-old daughter, Ms. Clarita P. Apostol, succeeded him. Ms. Apostol, the wife of a farmer-carpenter, had four children and was engaged in the production of rice, sugarcane, and vegetables.

B. The sericulture farm

The sericulture site was located on a 3-hectare property owned by the Costales-Molina Clan in Sitio Dadapilan, Lioac Sur, Naguilian, La Union, Philippines (Fig. 1). Mulberry fields could be established year-round in regions with an abundant water supply. The farmer's mulberry plantation was established in September 2011, coinciding with the intermittent rainfall from June to October, which helped reduce irrigation costs during the establishment phase. A total of 3,860 mulberry saplings were transplanted, including 1,500 of the NSIC Mb 01 variety, 1,410 of the Batac variety, 250 of NSIC Mb 02, and 700 hybrid varieties, spaced at 1.25 m × 0.5 m × 0.5 m from September 2011 to June 2020 in the underutilized areas at the front edge of the 3-hectare agricultural plot cultivated by the farmer.

Fig. 1. The mulberry plantation

The region had previously been used for cultivating rice, corn, vegetables, mangoes, bananas, and sugarcane, which served as the family's primary sources of income and sustenance. In addition to agricultural crops, the family raised chickens, goats, pigs, and rabbits, which were occasionally sold as income-generating ventures or kept for domestic consumption. They also raised cattle and carabao, which were used as draft animals during land preparation, transport operations, and to assist with various farm activities.

Table 2. Physical and chemical properties of soil and fertilizer recommendations of the Pulmano- Lioac sericulture site and the recommended rate of fertilizer for CY 2014

Physical properties				
BD g/cc	PD g/cc	Porosity %	Texture	
1.67	2.6	35	Medium	
Chemical properties				
pH	EC mS/cm	OM, %	Avail P, ppm	Exch K, ppm
6.0	0.23	3	88	420
Fertilizer recommendation				
Rate of recommendation			KG/HA/YR	
		N	P2O5	K20
		250	0	0

Table 3. Sericulture project overview: Farmer, location, and rearing details of the Pulmano/sericulture site in Lioac Sur, Naguilian, La Union, Philippines, CY 2012-2022

Name of farmer/ Location	Project in charge	Date started	Number of plants	Variety	Date rearing house constructed	Number of SW rearings /Number of boxes reared
LL	LP	Sept 2011	1410	Batac	Jun 2014	31 times /
Pulmano/	Apilado	Nov 2013	1000	Alfonso / S54 Hybrids		18.51 boxes
CP Apostol		Jun 2014	298	Alfonso		
		July 2015	500	S54/ SRDC/S13 Hybrids		
		August 2016	250	S54/ SRDC/S13 Hybrids		
		January 2018	100	S54/ SRDC/S13 Hybrids		
		June 2020	302=3860	S54/ SRDC/S13 Hybrids		

Mulberry leaf production/consumption

Mulberry was the sole food source for the silkworm, *B. mori,* making its cultivation essential to sericulture. The production of high-quality silkworm cocoons was crucial for the advancement of the silk industry. To achieve the goal of producing high-quality silkworm cocoons, several factors were significant: mulberry leaves (38.2%), climate (37.0%), rearing practices (9.3%), silkworm race (4.2%), silkworm eggs (3.1%), and other factors (8.2%) (Boraiah, 1988). Therefore, the quality and quantity of mulberry leaves were fundamental for sericulture and were critical for a successful silkworm cocoon harvest (Singh *et al.*, 2018).

Sericulture relied on the cultivation of silkworms fed exclusively on mulberry leaves; thus, silk output was directly correlated with larval development on mulberry. Leaves of exceptional quality increased the likelihood of a successful cocoon harvest (Ravikumar, 1988). Cocoon quality accounted for approximately 80% of raw silk quality, influenced by the mulberry leaves consumed by the silkworms (Boraiah, 1988). Additionally, Casagan (2020) stated that silkworms produced superior-quality cocoons when fed high-quality mulberry leaves, emphasizing the crucial role of the mulberry plant in cocoon production. Moreover, it was noted that approximately 1.2 to 1.5 kilometers of silk could be derived from a single cocoon, regardless of its size.

The soil and its physical and chemical characteristics

Composite soil samples obtained from the seri-site were air-dried, crushed, and subsequently sent to the Bureau of Soil and Water Management Laboratory in San Fernando City, La Union, Philippines for chemical analysis. Soil clods were collected and analyzed in the Soil Laboratory of SRDI to ascertain physical properties such as bulk density, particle density, and porosity. The findings from the soil chemical and physical examinations (Table 2) indicated that the location is extremely conducive to crop development, evidenced by an optimal soil pH, minimal electrical conductivity, and medium-textured soil. The soil organic matter (SOM) level was moderately elevated, necessitating an application of 250 kg N/ha/year, which involved the placement of 6 grams of Urea near the plant's base, followed by irrigation. The absence of P and K application is attributable to the exceptionally high levels of native accessible P and exchangeable K present in the soil.

Bulk density (BD) served as a metric for soil compaction. Bulk density increased with compaction and typically rose with depth. Soils with a bulk density greater than 1.6 g/cm³ often impeded root development. Sandy soils were more susceptible to elevated bulk density.

The area was strongly advised to improve the structure and fertility of the soil, thereby boosting productivity and enhancing mulberry leaf yield (Apilado *et al.*, 2021).

Mulberry plantation establishment

Table 3 delineated the mulberry transplanting history of the sericulture site at Lioac Sur, Naguilian, La Union, Philippines. Mulberry planting was conducted with the support of the Extension Staff of SRDI. Fungicide-treated mulberry saplings of the Alfonso, Batac, and Fruiting hybrids were supplied by the Sapling Production Unit of the Institute. A total of 3,860 mulberry trees were planted in the mulberry plantation, which was established in September 2011, November 2012, June 2014, July 2015, August 2016, January 2018, and June 2020. The trees were planted at a spacing of 1.25 m × 0.5 m × 0.5 m along the underutilized areas at the front edge of a 3-hectare agricultural plot.

The Institute's subject matter specialists demonstrated the appropriate cultural management measures for the farmer cooperators to implement in their future sericulture activities (Fig. 2). The manufacturer's recommendations were followed to disinfect saplings for transplanting, which were maintained and hardened in the SRDI nursery for five to six months. The saplings were treated with a fungicide solution. Transplanting schedules were typically implemented at the onset of the rainy season to take advantage of the abundant rainfall, minimizing irrigation costs during the establishment process.

Planting trenches were dug to a depth of 30 cm and a diameter of 15 cm to facilitate the penetration of plant roots into the soil, promoting rapid and extensive growth. Replanting of absent hills was conducted two weeks after transplanting to optimize land utilization and ensure consistency in crop establishment.

Fig. 2. Cultural management practices of mulberry

Selective pruning was carried out one-year post-transplantation, or when the plants reached approximately 6.5 feet (or less than 2 meters) in height, to enhance leaf production and improve its nutritional value for silkworm rearing. This process stimulated plant development, improving vitality and resulting in high-quality leaves. Sharp pruning shears or saws were used to prune the mulberry plants at a height of 50–60 cm above the ground, ensuring clean cuts that did not cause bark fissures (Dacayanan *et al.*, 1993).

Leaf and shoot plucking, or branch pruning, were employed to harvest mulberry leaves. Mature stems and branches were collected, cut into pencil-sized pieces, placed in jute sacks, watered daily, and planted in properly prepared seedbeds for sapling production after one week of incubation.

C. The rearing house

The rearing house, an open or garage-style structure with dimensions of 9m x 5m, was constructed in June 2014 with the assistance of a soft loan from SRDI. This arrangement enabled the farmer to raise a larger silkworm population. The farmer supplied wooden and bamboo racks, while the Institute provided Amazon plastic green mesh sheets for bed trays, cleaning nets, and black netting to enclose the rearing space during silkworm rearing periods.

D. Silkworm rearing management

The trial silkworm rearing schedule was initiated one year after the establishment of the mulberry plantation in 2012. Subsequent rearing schedules were implemented over the years, utilizing larger boxes for the cultivation of silkworm larvae.

The rearing house and its silkworm rearing equipment, including racks, beds, nets, and mountages, were thoroughly disinfected with a 10% hypochlorite solution for 2 to 3 days prior to the delivery of 4th instar silkworm larvae for each rearing schedule. A representative from the 4th Instar Larvae Unit of the Institute delivered the silkworms to the sericulture farm. The farmer reared the silkworms in accordance with the Institute's silkworm management policies and procedures, which included proper feeding schedules, bed cleaning, resuming or stopping feeding, and discarding and disposing of diseased worms at each instar stage of the life cycle. Sanitation, cleanliness, and orderliness were consistently maintained and monitored throughout the rearing process. The Project In-charge and Institute subject matter specialists closely supervised farm activities, particularly during critical periods such as fertilizer application, silkworm larvae delivery, feeding stop/resume, disease occurrence, mounting, harvesting, and hauling of cocoons (Fig. 3).

Fig. 3. Silkworm rearing activities and harvesting of fresh cocoons

Rearing performance of silkworms in lioac seri-farm

a. Silkworm races

The sericulture farm primarily employed DMMMSU 346, DMMMSU 406, and DMMMSU 408 in all silkworm rearing activities, with the exception of a few instances in which other varieties, such as DMMMSU 100 x 101, DMMMSU 103x102, and PTRI SW 04, were employed.

b. Number of silkworm cycles and number of boxes reared

Table 4 summarized the number of silkworm rearing cycles and the corresponding number of boxes reared from CY 2012 to CY 2022. Over the 11-year period, a total of 31 rearing cycles were completed, resulting in 18.51 boxes of silkworm larvae. On average, 2.818 rearing cycles were carried out each year, with an

average of 1.68 boxes produced annually. The number of rearing cycles fluctuated, with the highest recorded in 2019 and 2022 (4 cycles each) and the lowest in 2017 (only 1 cycle). Similarly, the number of boxes varied each year, with notable production in 2014 (2.75 boxes) and a low in 2017 (0.25 boxes). The number of boxes reared generally increased over the years, from 0.10 boxes in 2012 to 2.50 boxes in 2020, though there was a slight decline in 2021 (1.17 boxes). Overall, the production was steady but varied, averaging 1.68 boxes annually. Since 1 box equals 20,000 silkworms, approximately 370,200 silkworms were raised over the 11-year period.

Table 4. Silkworm rearing cycles and boxes reared from CY 2012 to 2022

Year	No. of rearing cycle	No. of boxes reared
2012	2	0.10
2013	3	1.40
2014	3	2.75
2015	2	2.50
2016	3	2.65
2017	1	0.25
2018	3	1.50
2019	4	1.50
2020	3	2.50
2021	3	1.17
2022	4	1.29
TOTAL	31	18.51
Ave	2.818	1.68

1 box = 20,000 silkworms

c. Actual cocoon yields and fresh cocoon sales

Table 5 presented the actual cocoon yield (in kilograms) and the corresponding cocoon sales (in Philippine pesos) from CY 2012 to CY 2022. The data showed significant fluctuations in both yield and sales over the 11-year period, with clear trends in market value and production levels.

In 2012, the cocoon yield was low, with only 2.30 kg produced as part of a trial, resulting in sales of PhP 460.00. From 2013 onwards, cocoon yield increased, reaching 35.00 kg in 2013 with sales of PhP 7,000.00. The yield peaked at 57.80 kg in 2014, yielding PhP 11,560.00 in sales. From 2014 to 2016, the yield remained relatively high, fluctuating between 47.00 kg and 48.30 kg, with corresponding sales. In 2016, the yield was 47.00 kg, with sales amounting to PhP 9,400.00. However, in 2017, there was a significant drop in both yield and sales, with only 3.80 kg of cocoons produced and sales of PhP 760.00, likely due to environmental or operational factors. From 2018 to 2022, the yield improved significantly, consistently exceeding 28 kg annually. In 2020, the yield reached 48.05 kg, and sales amounted to PhP 15,627.50, the highest recorded during the period. Sales remained strong in 2021 and 2022, with yields of around 35 kg and 44 kg, respectively. Over the 11 years, a total of 392.7 kg of cocoons were produced, generating PhP 94,935.00 in sales. The average annual yield was 35.7 kg, and the average annual sales amounted to PhP 8,630.45. The price of cocoons fluctuated from 2012 to 2019, categorized as "good" (PhP 200 per kg) or "bad" (PhP 60 per kg), depending on the quality of the cocoon, which influenced the annual sales figures.

Table 5. Annual cocoon yield and sales from 2012 to 2022

Year	Actual cocoon Yield, kg	Cocoon sales* Php
2012	2.30 trial	460.00
2013	35.00	7,000.00
2014	57.80	11,560.00
2015	48.30	9,660.00
2016	47.00	9,400.00
2017	3.80	760.00
2018	28.10	5,620.00
2019	42.75	8,550.00
2020	48.05	15,627.50
2021	35.55	10,981.50
2022	44.05	15,316.00
TOTAL	392.7	94,935.00
Ave	35.7	8,630.45

*Price per kilogram cocoon in PhP
(CY 2012-2019)= good (200/kg); bad (60/kg)
(CY 2020-2022) = good (350/kg); bad (60/kg

Other products derived from mulberry and silkworm

Other Benefits from sericulture

Sericulture, as a sustainable agro-sector, played a significant role in driving rural economic growth. It was considered a zero-waste enterprise, converting all byproducts into commercial goods and household materials while also being environmentally friendly. Although it required more labor than vegetable production, it demonstrated a faster return on investment (ROI). Elias (2016) noted that silkworms were not merely insects; they produced high-end

fashion fabric and provided a source of income for their keepers. Silk products, such as wedding dresses, sweaters, scarves, seat covers, handbags, baskets, and tablemats, were popular worldwide.

Sericulture boosted productivity on marginal lands, particularly in highland rain-fed areas where climate change had made fertile land unprofitable. As traditional agriculture became less viable, sericulture offered a sustainable alternative. Mulberry cultivation provided a reliable income while reducing soil erosion and improving soil fertility through composted silkworm dung. This synergy between sericulture and land conservation revitalized degraded lands, benefiting both the environment and local farmers.

In addition to cocoon production, pencil-sized mulberry stems were pruned for sapling planting. The family used the pruned stems as firewood, saving money and providing dried branches for their neighbors. Mulberry and vegetable cultivation benefited from the use of silkworm dung and decomposed mulberry foliage and branches as organic fertilizer.

Table 6. Summary of sales for various products in Lioac, Naguilian, La Union (2015-2022)

CY	Sales in Philippine peso									
	Cuttings	Saplings	Seeds	Fruits	Fruit juice	Vinegar	Wine	Novelty items	Compost	Total sales, PhP
2015	10,700		1,100	250						12,050
2016	3,200		1,000							4,200
2017	9,100			2,500		4,800				16,400
2018	6,800	1,000		6,550		22,425	6,000	16,940	2,000	61,715
2019	9,250			5,750	3,000	2,000	3,000		2,000	25,000
2020				6,250	6,000	5,500			4,000	21,750
2021				6,250	6,500	6,450			4,000	23,200
2022				1,500	3,000	2,400			5,000	11,900
Subtotal	39,050	1,000	2,100	29,050	18,500	43,575	9,000	16,940	17,000	
Grand total										176,215

Table 6 presents the sales of various products in Lioac, Naguilian, La Union, from CY 2015 to 2022. Total sales fluctuated each year, with cuttings consistently generating the highest revenue, followed by saplings and fruits. In 2015, total sales were PhP 12,050, primarily from cuttings (PhP 10,700). Sales peaked in 2018 at PhP 61,715, driven by cuttings (PhP 6,800), fruits (PhP 22,425), and processed items like fruit juice, vinegar, and wine. The total sales for the period amounted to PhP 176,215, with cuttings and saplings remaining the main contributors.

a. Marcotted sapling and cuttings

The mulberry plantation expanded, and trimming activities were conducted biannually to promote fresh leaf growth for feeding during subsequent silkworm rearing. Mature branches and stems were harvested and trimmed to pencil length (3-4 nodes). Marcotted plants were also propagated from the mulberry fruiting hybrids. Some cuttings were sold to the SRDI for sapling production, while others were marketed and sold online through Facebook to plant collectors and gardening enthusiasts, generating a total revenue of PhP 40,050.00.

b. Mulberry fruits

Throughout the project, the El Niño phenomenon caused severe leaf fall, but this prompted 450 fruiting-type mulberry plants to transition to the fruiting stage, producing an abundance of large, sweet fruits that were carefully harvested during the dry season. Over 11 years, a total of 217 kg of fresh mulberry fruits was collected, generating PhP 102,225.00 in income. The ripe fruits were sold fresh, while some were cooked, mashed, and the juice extracted, bottled, refrigerated, and sold online for their antioxidant benefits. Seeds from selected hybrid fruits were also collected, cleaned, air-dried, and stored in sealed containers. These products were promoted via a Facebook gardening page.

Fig. 4. Mulberry wine and vinegar products

c. Mulberry fruit juice, wine and vinegar

Selected ripe fruits were boiled and processed into fruit juices, flavorful vinegars, and table wines (Fig. 4). These products were promoted on Facebook.com, resulting in an income of PhP 71,075.00.

d. Composted materials and fuelwood

Silkworm byproducts were collected during each cultivation cycle, air-dried, and stored in plastic containers. A total of 1,700 kg of organic refuse was gathered and used as fertilizer for the farmer's rice crops, saving Php 17,000 on fertilizer costs for rice, mulberry, vegetables, and sugarcane production. The addition of organic residues improved soil fertility, porosity, and aeration. Diseased silkworms were treated with a 5% hypochlorite solution before being burned or buried. Plant parts, including branches from leaf harvesting, were dried and used as fuelwood, while excess leaves were fed to livestock like goats and calves.

Fig. 5. Novelty items making

e. Novelty items making

The farmer and her two children generated a gross income of PhP 16,940 from the sale of novelty items, including rose flowers, birds, bouquets, wedding mementos, and corsages, that were crafted from cut cocoons purchased from the One-Stop Shop of SRDI in CY 2018. This activity is illustrated in Fig. 5. An average ROI of 63.20% on novelty items products, and 176 % and 56.6% for mulberry wine and vinegar, respectively.

Table 7. Financial summary of product sales, costs, and net income from 2012 to 2022

Products	Year											Total	Ave
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
Cocoons	460	7,000	11,560	9,660	3,400	760	5,620	8,550	16,975	10,622.50	15,417	90,024.5	
Cuttings				12,300				8,250				20,550	
Saplings													
Novelty items							16,940					16,940	
Fruits				500		2,500	6,500	3,750	5,000	6,250	1,500	26,000	
Wine							6,000					6,000	
Vinegar						4,500	22,485	2,000	5,000	6,400	2,400	42,785	
Fruit juice							1,825	3,000	6,000	6,500	3,000	20,325	
Total sales	460	7,000	11,560	22,460	3,400	7,760	59,370	25,550	32,975	29,772.5	22,317	222,624.5	20,128.59
Less													
Direct cost	2,146	5,891	10,536	9,156	11676	16,116	23,019	18,106	14221	9,071	8,591	128,529	11,684.45
Indirect cost							3,100	2,500	2,500			8,100	736.36
Capex	129,399	129,399	129,399	129,399	129,399	129,399	129,399	129,399	129,399	129,399	129,399		
Net income	-1024	-1024	1,024	1,516	8,296	8,356	33,251	806	15,254	25,951.50	13,726.50	106,132.5	9,648.41
ROI, %	-11.75	-11.75	11.75	17.40	-94.97	-95.89	381.58	-9.25	175.05	297.82	157.52	817.51	74.32

g. Return of investment

Table 7 provides a financial overview of various products from 2012 to 2022, highlighting sales, costs, net income, and ROI. Cocoons consistently generated the highest revenue, totaling PhP 90,024.50, with significant peaks in 2020 and 2022. Fruits and vinegar also contributed notably, with fruits generating PhP 26,000 in 2019 and vinegar reaching

PhP 42,785. Other products, such as cuttings, saplings, wine, and fruit juice, contributed smaller amounts to overall sales. Direct costs fluctuated over the years, peaking at PhP 16,116 in 2020, while indirect costs were recorded in select years, with significant expenses in 2016 and 2017. Capital expenditures (Capex) remained constant at PhP 129,399 annually. Despite negative net income in some years, particularly in 2012, 2013, 2015, and 2016, net income became positive from 2014 onward, peaking at PhP 25,951.50 in 2020. The ROI was negative in the earlier years but showed substantial improvement, particularly in 2018 (381.58%) and 2020 (175.05%). The overall ROI for the period was 74.32%, indicating a shift toward profitability, primarily driven by cocoon sales and value-added products like vinegar and fruit juice.

Conclusion

The Don Mariano Marcos Memorial State University Sericulture Research and Development Institute (DMMMSU-SRDI) aimed to enhance the productivity of sericulture farmers and increase the income of marginal farmers by promoting optimal sericulture production techniques. The project also sought to provide gainful employment to out-of-school youths and other community members while meeting the demands of domestic and international markets for silk and related products.

The Sericulture demonstration farm, initially managed by Mr. Ludovico L. Pulmano and later by his daughter Ms. Clarita P. Apostol, was established on a 3-hectare property in Sitio Dadapilan, Barangay Lioac Sur, Naguilian, La Union, Philippines, from 2011 to 2022. The farm primarily generated income from grain production, vegetable farming, animal raising, sugarcane, vinegar/wine production, and other business ventures, with sericulture serving as a subsidiary occupation.

The project began with the mulberry plantation in September 2011, expanding until June 2020, with a total of 3,860 mulberry seedlings planted. The silkworm growing study commenced in 2012 and continued annually until 2022. The farm's soil, with favorable pH levels, organic matter, and nutrient content, proved ideal for mulberry cultivation. Fertilization was managed with 250 kg of NPK fertilizer per hectare annually, applied in five sessions throughout the cropping year.

Favorable climatic conditions generally supported the production of high-quality cocoons, but the effects of climate change and a disease outbreak in 2017, along with the COVID-19 pandemic in 2019, posed challenges to the silkworm production. Despite these setbacks, significant progress was made, with 31 rearing cycles completed, yielding a total of 392.7 kilograms of fresh cocoons over 11 years. Farm revenue from sericulture reached PhP 94,935, complemented by additional income of PhP 176,215 from allied products such as fruits, cuttings, saplings, novelty items, fruit beverages, vinegar, wine, and composted materials.

The project demonstrated a high return on investment (ROI), reflecting the promising potential of sericulture as a sustainable income-generating activity for marginal farmers in the region.

Recommendations

Expansion and Replication: The success of the sericulture project in Lioac Sur, Naguilian, La Union, Philippines indicates its potential for replication in other underutilized and marginal lands with comparable or diverse agroclimatic conditions. Efforts should concentrate on pinpointing appropriate regions and involving additional farmers.

Capacity Building: Implement frequent training initiatives for farmers to improve their expertise in mulberry farming, silkworm rearing, and by-product usage, hence ensuring increased productivity and superior quality outputs.

Support Systems: Enhance support services by facilitating access to loans, superior inputs, pest management strategies, and ongoing technical assistance to tackle obstacles and ensure project sustainability.

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