Journal of Sustainability Science and Management
Volume 18 Number 8, August 2023: 37-49
eISSN: 2672-7226

GAP RUBBER FARMING AND A GMP LATEX COLLECTION CENTRE WITH A BCG ECONOMY MODEL IN THAILAND

TASSANAKUL PREPRAME[1] AND SOMBOONSUKE BUNCHA[2]*

[1]Rubber Industry Division, Rubber Authority of Thailand, Hat Yai, 90250 Songkhla, Thailand. [2]Department of Agricultural Innovation and Management, Faculty of Natural Resources, Prince of Songkhla University, Hat Yai Campus, 90112 Hat Yai,, Thailand.

*Corresponding author: buncha.s@psu.ac.th
Submitted final draft: 6 March 2022 Accepted: 11 May 2023 http://doi.org/10.46754/jssm.2023.08.003

Abstract: The Bio-Circular and Green Economy (BCG) model has been applied in Good Agricultural Practices (GAP) on rubber plantations and Good Manufacturing Practices (GMP) for Latex Collection Centres (LCC). An agricultural cooperative group, Trang Province (Thailand) applied GAP and GMP to successfully implement its BCG economy for better sustainability. The results revealed that farmers applied knowledge to their bio-economy for rubber farming to enable them to produce high-quality fresh latex resulting in an increased yield of 28.95%. The standardisation of fresh latex had set the minimum dry rubber value content at 30%, the maximum volatile fatty acid at 0.07 units, and the minimum of ammonia at 0.20% allowing concentrate latex manufacturers to accept and trust in the quality of raw materials. An analysis was done of the economic situation. The study found that the investment by the LCC had an NPV greater than zero. The BCR and IRR values were greater than 1 and 20%, respectively. These indicated the worthiness of an investment. This also has the benefit of recovering rubber scraps in wastewater, which can be used to produce rubber sheets. These create added value and enhance the production of latex in a sustainable manner for rubber farmer groups.

Keywords: Bio-circular economy, good agricultural practice, good manufacturing practice, Green Economy, sustainable manner.

Introduction

Global economic challenges and international commitments must address climate change. Thailand is embracing the Bio-Circular and Green Economy (BCG) model as a path toward sustainable growth. This involves the reduction of resource use, resource renewability, and the development of an eco-friendly society (Bangkok Post, 2020; Norsuwan *et al.*, 2021). Good Agriculture Practices (GAP) on rubber plantations and Good Manufacturing Practices (GMP) for rubber processing plants are based on the principles of a BCG economy. (Rubber Authority of Thailand, 2022).

Good practices and best management techniques can increase yields, extend the lifespan of latex preservation, and enable the long-term harvest of latex (Kangpisadan, 2006; Gohet & Regis, 2016). A bio-economy focuses on the cost-effectiveness of ecosystems, livelihoods, and the well-being of people. It is based on increasing the land use capacity and income opportunities of sustainable land management (Chiarawipa, 2019). A circular economy with proper management processes can increase productivity, add value, and reduce pollution in rubber processing. A green economy focuses on the quality of fresh latex from GAP farms to Latex Collection Centres (LCC), personal safety, and reduced use of agrochemicals. At the heart of the GAP concept, organic fertiliser has been recently used as a substitute for chemical fertiliser and reduced pesticide application in farming (Schreinemachers *et al.*, 2012). Hong Van *et al.* (2001) reported that fertiliser is one of the most important factors that improve the growth and yield of rubber trees. Not only will the yield increase in the long term but also the fertility and functions of the soil will be improved.

GAP for fresh latex was promoted as an agricultural standard by the National Bureau of Agricultural Commodity and Food Standards

(ACFS) and the Rubber Authority of Thailand (RAOT) (TAS 5908-2019). This was to achieve the best value for investment and increase productivity by at least 20% (Chantuma, 2020). Desirable fresh latex is characterised by its high quality that easily meets the requirements of users. Applying GAP and GMP principles can reduce waste, increase productivity, and minimise the environmental impacts to supply fresh latex. Then, latex can subsequently be made into concentrated latex, ribbed smoked sheets, airdried sheets, pale crepe rubber, and block rubber (STR5L) at premium grade (Tassanakul, 2019). Currently, more than 90% of fresh latex in the southern part of Thailand is transformed into concentrated latex and unsmoked sheets. Nevertheless, with the COVID-19 epidemic, the global rubber glove market continuously expanded, causing up to 20% higher prices for fresh latex throughout 2019-2020 (Kanjanavisut, 2020).

Concentrated latex production became inadequate to meet the demands of the global market. Encouraging farmers to engage in good practices from the farm to the end of transportation, and ensuring the quality of fresh latex without contamination will lead to reduced downstream processing costs of at least 0.08 USD per kilogram (Phanmai, 2021). From the study of Tassanakul (2019), the problem mostly concerns fresh latex properties, which are often not good enough to produce high-grade concentrated latex. Volatile Fatty Acid (VFA) levels were greater than 0.07 caused by an uncontrolled tapping system and period (Tassanakul, 2021a). Dry Rubber Content (DRC) of fresh latex was lower than 28% due to the tapping depth reached into the cambium of the rubber tree and high frequency tapping practices resulted in increased bark consumption as well (Chantuma, 2008). Fresh latex from farms was not filtered through a sieve to separate contaminants and improperly used preservatives.

Production of high-quality latex complying with GAP principles must start by tapping after midnight, upside down of collection cups after collecting fresh latex, filtering fresh latex several times starting in the field, and delivering fresh latex to a collection centre before 11.00 a.m. (Rubber Research Institute of Thailand, 2020). Furthermore, GMPs at the latex collection centres play a crucial role in preserving latex quality to meet customer requirements.

GMPs for Latex Collection Centres (LCCs) were promoted as ACFS agricultural standards by RAOT (TAS 5911-2021). These criteria cover 6 items:

(1) Establishment is not damaged and without flood.
(2) Materials and equipment must be enough, ready to use, and easy to operate.
(3) Processing must be followed by a strict quality system.
(4) Personals should understand and enjoy the work.
(5) Storage and transportation should be orderly and without risk.
(6) Sanitation must be clean and safe.

It is a system for ensuring that fresh latex is consistently produced and controlled to meet its quality standards. The goal is to minimise the risks involved in rubber production that cannot be eliminated through testing the final product. GAP and GMP with a BCG economy model are shown in Figure 1.

Thus, a study was conducted with the aim to improve the quality of natural rubber and enhancing the standard of agricultural products in Thailand for commercial competition. The main objective of this study was to investigate the implementation of a BCG economy along with GAP on farms and GMP at an LCC (TYAC received its GMP certification from RAOT in 2021) and calculate the yields of fresh latex. The second objective was to ascertain that the properties of fresh latex met the quality standards of the Rubber Authority of Thailand (RAOT). The third objective was to analyse the cost of investments to create balance and sustainability in several dimensions. The final objective was to recover rubber scraps in the production line to reduce offensive odours and increase added value.

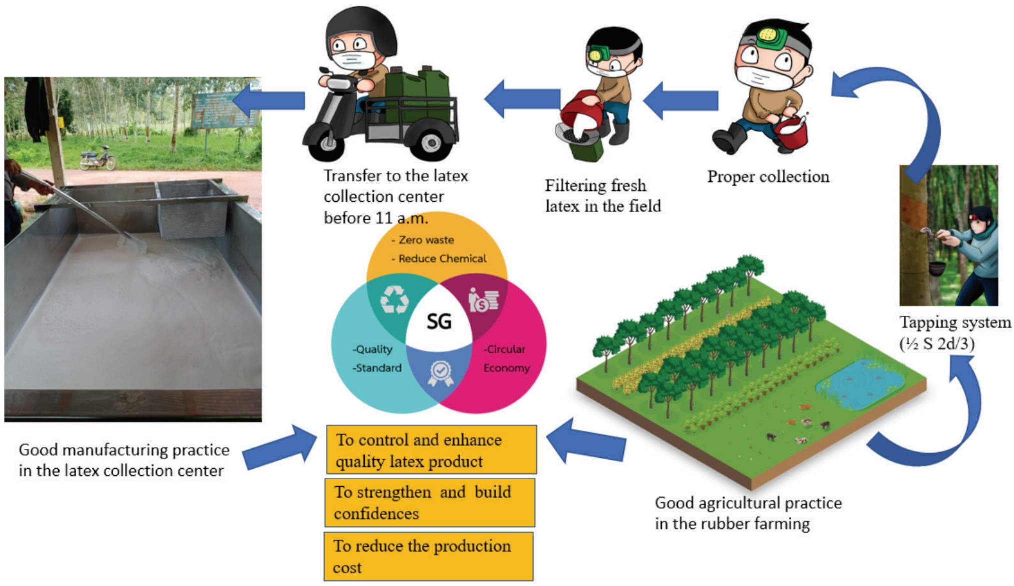

Figure 1: Sustainable goal for GAP and GMP with a BCG economy model

Materials and Methods

Knowledge Assessments

The study was conducted between March 2020 and April 2022 at Thung Yoa Agricultural Cooperative Limited (TYAC), a rubber producer, in Trang Province, located in the southern region of Thailand. Quantitative research data collection was done by a purposive sampling method (Pakchareon, 2012) selecting 30 out of 132 rubber farmers with no return sampling (Poonlabthawee, 1996). Before and after knowledge assessments were undertaken using fixed-response tests. The quiz assessments consisted of 15 questions related to GAP for latex production and 15 questions related to GMP for latex collection. The process used mean values of dependent samples in paired t-tests.

BCG Economy Model Analysis

The BCG economy for the 132 members of TYAC consisted of 3 main bioeconomies. The first is one focused on managing rubber farming that complies with GAP standards. The process used organic fertilisers integrated with chemical fertilisers according to soil analysis or recommendations. The second is a circular economy focused on tapping system management that does not cause injury to the cambium of rubber trees, tapping from midnight to 6.00 a.m., filtering latex in the field, and delivering to the Latex Collection Centre (LCC) not later than 11.00 a.m. (Tassanakul, 2021b). The third is a green economy is focused on GAP and GMP recommendations such as maintaining cleanliness on the plantation and working areas, using proper preservatives and coagulating rubber scraps using organic chemicals, among others. This experiment was conducted using GAP (TAS 5908-2019) and GMP (TAS 5911-2021) recommendations.

Recommendations for Fresh Latex GAP

The production of fresh latex before the GAP introduction involved fertilising the soil just once a year. It was done inappropriately, resulting in low yields. Agrochemicals were used that had the potential to cause serious health effects. The tapping system and tapping system management caused injury to the cambium of rubber trees. Tapping angles were inappropriate, less than 30 degrees or more than 35 degrees, which reduced latex yield. The tapping time was too long. Tapping was done during the period of 10.00 p.m.–08.00 a.m. causing latex deterioration. Fresh latex was not filtered in the field allowing it to be delivered to the latex collection centre in a contaminated condition.

This was corrected by the introduction of the appropriate GAPs. Organic fertiliser was applied appropriately, reducing the use of chemical fertilisers. No agrochemicals were used, eliminating a serious safety hazard. A tapping system was adopted that followed RAOT recommendations. Tapping angles were limited to 30-35 degrees to increase productivity. The tapping time was shortened from midnight to 6.00 a.m. This helps maintain the freshness of latex. Filtering fresh latex in the field increased DRC values. The details of this process are shown in Table 1.

Recommendations of LCC GMP

The collection of fresh latex before the introduction of GMPs presented several serious difficulties. The collection centre equipment and facility were very dirty. Incoming latex was not filtered or filtered once using a 5 mesh (4 mm) filter that did not remove all contamination. The bulking tank was lined with floor tiles. This allowed contamination with foreign material from the grout between the tiles and the tank was difficult to clean. The process used a high concentration of an ammonia solution affecting operators and latex quality. The latest latex delivery was 12.00 a.m. which allowed time for latex deterioration. The latex rinse water contained latex particles. This water was discharged into the local sewer system causing strong odours that negatively impacted the community and the environment.

Collection of fresh latex according to GMPs resulted in a very clean establishment and orderly arranged materials and equipment. Fresh latex was filtered twice more using fine sieves to obtain clean latex. The bulking tank was made of stainless steel to prevent contamination and it is easy to clean. Latex is delivered before 11:00 a.m. to desire as fresh as possible. Ammonia content was used at a rate of 0.20-0.25% on fresh latex by preparing a 6% stock solution to reduce the disintegration of young lutoids in the latex. Co-act L was used as a coagulant (2 ppm polyacrylamide with 0.04 M buffer) to decompose proteins in crumb latex and reduce odours. The details of this process are shown in Table 2.

The yield of latex on a wet-weight basis was analysed by comparing samples with and without the GAP and GMP criteria. Two rubber clones (RRIM 600 and RRIT 251), aged 15-25 years were used. RRIM 600 is the most planted variety in Trang Province.

Fresh Latex Specifications

To determine the ROAT specifications, the data was collected as six latex samples per week for approximately seven months (28 weeks), resulting in a total of 168 samples. Each sample was 100-150 grams, collected by random sampling from the TYAC members. Fresh latex properties including dry rubber content (DRC), VFA, and ammonia were analyzed using standard methods, ISO 126, ISO 506, and ISO 2004, respectively (ISO 126, 2005; ISO 506, 2020; ISO 2004, 2017).

Worthiness of Investment

Economic metrics indicative of the worthiness of investment by an LCC such as Net Present Value (NPV), Benefit Cost Ratio (BCR), and Internal Rate of Return (IRR) were analysed (Boardman *et al.*, 2018). A determination of feasibility was made.

Measurement of Influent and Effluent Wastewater from the LCC

The environmental metrics, including pH, Total Suspended Solids (TSS), and Biochemical Oxygen Demand (BOD) of wastewater in the influent and effluent water were analysed (American Public Health Association, 1999). On-site measurement of pH was carried out using

Table 1: GAP (TAS 5908-2019) recommendations compared to the conventional system for mature rubber tree

System	Fertilisation (kg/tree/year)		Agrochemicals	Harvesting System		Duration of Tapping	Collection System
	Organic Fertiliser	Chemical Fertiliser		Tapping System[1]	Tapping Angle		
Conventional practice	in 1st app. 0-1	- in 1st app. 0.5 kg of 15-15-15 NPK - 16-16-8 NPK	1. Paraquat 2. Glyphosate according to the recommendations or more than recommended	3S d/4 S 2d/3 3S d/4	- Less than 30 degrees - more than 35 degrees	10.00 p.m. – 8.00 a.m.	No filtering latex in the field
GAP	in 1st app. 2-3	- in 1st and 2nd app. 0.25 kg of 30-5-18 NPK - 29-5-18 NPK - Apply fertiliser according to soil analysis	- none - integrated plant management: Pepper, coffee	S d/2 S d/3 S 2d/3 S 2d/3	30-35 degrees	Midnight-6.00 a.m.	Filtering latex in the field (filter 7 mesh, 3 mm)

Note: [1]The tapping system for GAP recommendation consisted of four levels; 1) half-spiral downward tapping, one day tapping in two days (½ S d/2), 2) half-spiral downward tapping, one day tapping in three days (½ S d/3), 3) half-spiral downward tapping, two days tapping in three days (½ S 2d/3), and 4) one-third spiral downward tapping, two days tapping in three days ($^1/_3$ S 2d/3)

Table 2: GMP (TAS 5911-2021) recommendations compare to the conventional system on LCC

System	Cleanliness in the Working Area	Collection Latex System					Using Organic Chemicals for Coagulating Rubber Scraps	Odour
		Filter Size, Diameter (Mesh, mm)	Filtration (Times)	Bulk Tank (Type)	Stock Solution Ammonia (%)	Delivery Time (Before)		
Conventional practice	dirty	5, 4	1	Floor tiles	12	12.00 a.m.	none	offensive
GMP	clean	in 1st 10, 2 in 2nd 18, 1	2	Stainless steel	6	11.00 a.m.	Co-act L (coagulant)	None

a pH meter. TSS content in the collected water samples was determined using a gravimetric method. BOD in water was determined using the difference in the dissolved oxygen (DO) levels of water samples prior to incubation and after 5 days of incubation (BOD_5). The samples were transported in an ice chest to our laboratory and preserved in a refrigerator prior to analysis. The results of effluent water analysis were compared with the standards for controlling wastewater from industrial factories of the notification of the Ministry of Natural Resources and Environment (2016).

The Added Value of Recycling Rubber Scraps

The added value of recycling rubber scraps in effluent water was also studied using total solid content analysis (ISO 124, 2014).

Results and Discussion

Assessment of Farmer Knowledge Before and After Implementing GAP/GMP for Rubber

Achievement of knowledge for GAP-rubber farming and GMP-LCC was studied among 30 farmers of the sample group at TYAC, Trang Province. The rubber farmers were trained by a "Rubber Teacher" with strict compliance in transferring knowledge. The data showed that rubber farmers increased their knowledge after receiving training on GAP and GMP principles. Statistical analysis of dependent samples using a paired t-test of the pre-and post-test mean scores showed a statistically significant difference at a 95% confidence level, as shown in Table 3. With this training, farmers can better do rubber production and understand latex collection management.

Yield Before and After Implementation from GAP for Rubber Farming and GMP for LCC

TYAC has an average production capacity of 15 metric tons per day on fresh latex. The result showed that the yields of TYAC before the implementation of GAP and GMP practices from May 2020 to February 2021 and after GAP and GMP from May 2021 to February 2022 were 1,080,248.22 kg and 1,393,053.68 kg, respectively. This is an increase of 28.95%, equivalent to increased revenue of approximately 340,000 USD per year. The results indicated that the tapping angle adjustment between 30-35 degrees is appropriate to increase yield, and tapping caused no injury to the cambium, as shown in Figures 2 and 3. This is consistent with the empirical research of Chantuma (2007) who reported that the tapping angle could be adjusted from 40 degrees to 30-35 degrees to increase yield by 2-3%. Latex vessels in the bark are oriented at an angle of 2 to 7 degrees from the vertical, low left to high right. Hence a cut from the high left to the low right opens the maximum number of latex vessels (Riches & Gooding, 1952). Not only has been increased productivity of rubber trees but fresh latex has also risen in DRC as well. Additionally, tapping rubber trees after midnight and finishing by 6.00 a.m. will increase the yield by 16% compared to stopping at 10 a.m. since pressure and temperature will result in a slower dripping time (Phaechana *et al.*, 2011).

The Rubber Research Institute of Thailand (2020) recommends that organic fertilisers be used at the rate of 2-3 kg per tree per year to maintain the physical and biological properties of the soil and ensure high productivity. This study is consistent with the empirical research

Table 3: The results of training on GAP-rubber farming and GMP-LCC at the TYAC, Trang Province, Thailand

Test scores	n	mean	SD	t	Df	sig
Pre-learning	30	11.63	2.72	9.32	29	1.58E-10
Post-learning	30	15.87	2.24			

Note: Statistical significance level of .05

Figure 2: Before GAP implementation, tapping caused injury to the cambium with a 40 degrees angle

Figure 3: After GAP implementation, tapping caused no injury to the cambium with a 30-35 degrees angle

of Kangpisadan (2013) showing that chemical fertilisers mixed with organic fertilisers used according to instructions produced yields that were 6–38% higher than that of traditional practice thus promoting economic growth. If farmers utilise the proper technology, their yields will increase by more than 10%, depending on the suitability of the area and rubber farming system (Tassanakul, 2021a).

In the GMP implementation at the LCC, filtering fresh latex with a sieve as a recommendation can produce quality rubber consistently and reduce the deterioration of the latex because some of the coagulated latex begins to lose its charge and change to a positive charge. The rubber particles were distributed in the latex, originally negatively charged rubber particles repel each other, and will be combined with the positively charged rubber lump causing the lump to become larger and reducing DRC. The criteria of ammonia content were used at a rate of 0.20-0.25% on fresh latex. If a higher concentration or a large amount of ammonia was attained, the fresh latex would be increased viscosity during prolonged storage (Santipanusopon & Riyajana, 2009). The application of appropriate technology with GAP and GMP standards results in a bio-economy centered around a rubber farming system (Tables 1 & 2). The resulting products have more consistent properties and higher yields, as shown in Figure 4.

Specification of the Properties of Fresh Latex

The 168 samples of fresh latex were collected from members of the TYAC using the best harvesting management and latex collection practices. The specific latex properties examined were DRC, VFA, and ammonia content. These test results showed that the DRC, VFA, and ammonia levels were 33.41% (SD of 1.95), 0.036 units (SD of 0.041), and 0.02% (SD of 0.03), respectively. It is necessary to add an ammonia solution at the latex collection centre to meet the buyer's specifications before delivery to the concentrating factories. The Rubber Industry Division of RAOT initiated quality control management standards in the form of GAP and GMP to control the quality of products throughout production from the farm to the end of factory processing. The ROAT proposed GMP criteria at LCCs as an established agricultural practice and this was upgraded by the Agricultural Standards Act (TAS 5911-2021). RAOT specifies the properties that are necessary for fresh latex shown in Table 4.

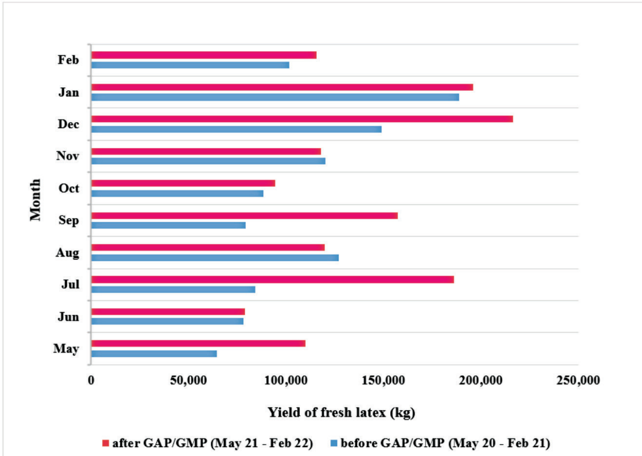

Figure 4: Comparison of latex yields at TYAC, Trang Province, before and after implementing GAP/GMP practices in 2020-2022

Cost-benefit Analysis of the Investment Project

TYAC has an average annual production capacity of 1,300 metric tons of fresh latex. It is a project with an initial investment of 54,285 USD and a net present value (NPV) of 22,838 USD. The payback period of this investment was determined from the NPV for the first, second, and third years of 8,570, 17,140, and 34,285 USD, respectively, showing a payback period of 2.83 years. It is a worthwhile investment. This project has a benefit-cost ratio (BCR) of 1.74, indicating that the return arising from the investment more than offsets the expenses encountered. The Internal Rate of Return (IRR) is 20.9%, which makes it an attractive investment since the current discount rate (cost of borrowing the money) is 7%. It represents a viable investment project, as shown in Table 5.

Waste Management in Production and Operation

Rinse water is obtained after washing containers, filters, collection ponds, or latex trucks. Traditionally, it is discarded with no treatment process. Unpleasant odours at wastewater treatment plants cause annoyance

Table 4: Specification of the properties of fresh latex

Properties	Test Results	Criteria	Standard Method
Dry rubber content[1], % by weight	33.41 (1.95)	Min 30.00	ISO 126
Volatile fatty acids[2], units	0.036 (0.04)	Max 0.07	ISO 506
Ammonia content, %	0.02 (0.03)	Min 0.20	ISO 2004

Notes: [1]Dry Rubber Content is defined as the mass in grams of rubber present in 100 g of latex. [2]Volatile Fatty Acid is defined as the number of grams of potassium hydroxide equivalent to the volatile fatty acids in latex concentrate containing 100 g of total solids. The standard deviations of the test results are described in the parenthesis.

Table 5: The results of the cost-benefit analysis of the investment project

Initial Investment (USD)	Net Cash Inflows (USD)	Payback Period (year)	BCR (times)	NPV (USD)	IRR (%)
54,285	60,000	2.83	1.74	22,838	20.9

to the community and negatively impact the environment. In the processing line of TYAC, water is used to rinse the containers and trucks at an average rate of 1.5 cubic meters per day or 1 cubic meter of rinse water per 10 metric tons of fresh latex. There is an average of 2% dry rubber content (DRC) in the rubber scraps remaining in the rinse water. TYAC can recover rubber scraps to make rubber sheets or unsmoked sheets at an average of 30 kg per day using Co-act L as a coagulant and create added value of at least 1.39 USD per sheet or 3,870 USD per year (Figures 5-7). Therefore, a circular economy with proper management processes can recover rubber scraps and increase income from trucks, containers, and filters. It adds value to pay the wastewater management expenses, 0.05 USD of Co-act L per 1 kilogram of rubber recovered, and concurrently reduce offensive odours from accumulated rubber scraps.

Through effective management of the rinse water from the equipment, the rubber scraps were removed from the wastewater. This eliminated negative impacts (odours) on the community. Wastewater analysis showed that the properties of water in the treatment pond were pH 7.1, TSS 86 mg/l, and BOD_5 12 mg/l. Before wastewater treatment, the wastewater had a BOD_5 of 1,250 mg/l, which represents a removal efficiency of 99.04% (Table 6).

Based on the study results, the BCG economy model along with GAP and GMP of rubber production (Figure 8) approved the enhancements not only in efficiency of latex production, but also environmental and economic benefits.

Figure 5: Rinse water from the fresh latex tanks and trucks to produce the rubber sheets

Figure 6: Coagulated latex scraps with Co-act L to produce rubber sheets

Figure 7: Rubber sheets from rinsing water of latex

Table 6: Properties of wastewater discharge at TYAC Trang Province, Thailand

Properties	Test Results		Removal Efficiency (%)	Standard[1]
	Influent	Effluent		
pH	7.5	7.1	-	5.5-9.0
TSS[2], mg/l	505	86	82.97	< 150
BOD_5[3], mg/l	1,250	12	99.04	20

Note: [1]Ministry of Natural Resources and Environment of Thailand (2016). [2]Total Suspended Solids (TSS) are defined as solids in water that can be trapped by a filter. [3]Biochemical Oxygen Demand (BOD) represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic conditions at a specified temperature in 5 days.

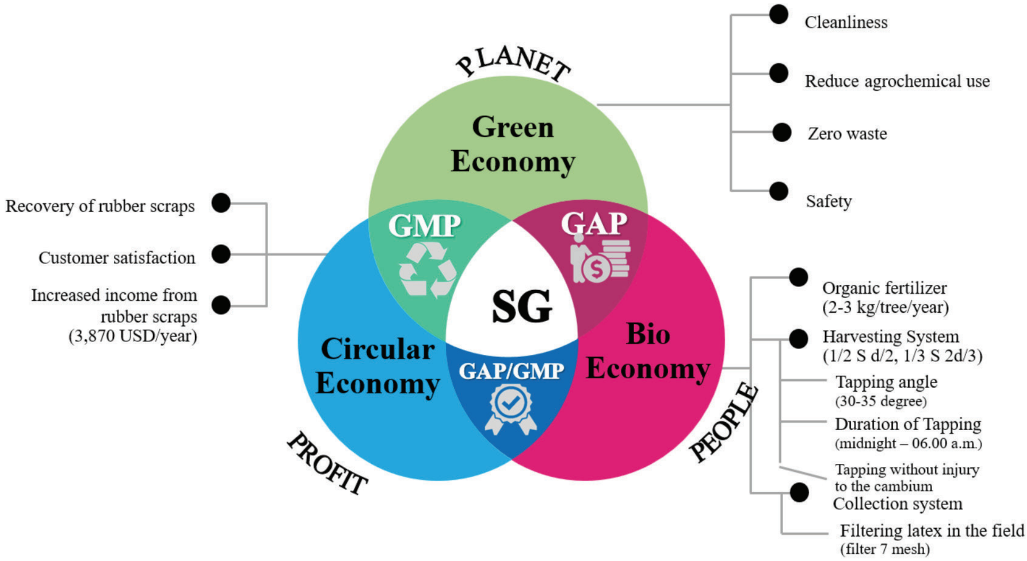

Figure 8: Sustainable Goals (SG) according to the BCG economy along with GAP for rubber farming and GMP for LCC

Conclusion

The assessment GAP training for rubber farmers indicated that almost all learners were developing an understanding of the content. The rubber farmers achieved significantly higher scores after learning than before. They were able to improve their knowledge and apply it in practice as well as being motivated to learn. From a research point of view, RAOT has received complaints from concentrated latex entrepreneurs about the quality of fresh latex collected from rubber farmers' groups inconsistent quality and has not met market requirements. Therefore, the researcher implemented GAP and GMP standards for producing fresh latex in the field and LCC to add value. These practices improve the rubber bio-economy. Farmers have improved their agricultural productivity, ensured a better living, long-span rubber farming, and have continued support of RAOT. The agricultural bio-economy will be strengthened, resulting in social, economic, and environmental benefits. TYAC has engaged businesses with a good vision for operations that have driven the group to become a strong model for moving towards stability and sustainability according to Thailand's national strategic plan. GAP rubber farming and GMP LCCs can be conducted in a BCG economy as a path toward sustainable growth. TYAC is an excellent model for communities, the economy, and the environment.

The RAOT has also been promoting the GMP system for LCCs to promote highly consistent quality, high productivity, and lower production costs, as well as reduce environmental pollution. The rubber consumers have been satisfied with the supplies of raw natural rubber from GMP and GAP-certified producers. Not only has the quality been consistent, but traceability from farm to factories and sustainability of rubber farmer group have also been achieved. Recently, Michelin company has demanded at least 1,000 tons of fresh latex per month from the GMP-certified latex collection centres through RAOT. Therefore, the adoption of GAP in conjunction with GMP for collecting latex is a cost-effective business practice for sustainable profit and growth.

For a circular economy, the rinse water scrap was coagulated using a commercial product

(Co-act L) to recover rubber scraps and produce rubber sheets at a rate of 30 kg per day with an average price of 1.39 USD per kilogram. This treatment can also contribute towards reducing pollution in the environment by making it a zerowaste system to be a green economy. The added value from rubber sheets made from rubber scrap is not less than 3,800 USD per year. The offensive odour around the production area has been eliminated, preventing air pollution in a sustainable and profitable manner. Added value was achieved by creating a bio-circular green economy in recycling this waste.

Acknowledgements

The authors would like to thank the Rubber Authority of Thailand and Faculty of Natural Resources, Prince of Songkla University for financial support. We are also grateful to Dr. Jeffrey C. Nash, technical editor of Khon Kean University of Thailand, for assistance with manuscript preparation. We extend our gratitude to Assoc. Prof. Dr. Tawat Chittrakarn for his critical comments on the manuscript.

References

American Public Health Association. (1999). *Standard methods for the examination of water and wastewater.* American Public Health Association, American Water Works

Association, Water Environment Federation. Retrieved June 10, 2022 from http://www.standardmethods.org

Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L. (2018). Cost-effectiveness analysis and cost-utility analysis. In *Cost-benefit analysis. Concepts and practice* (5th ed., pp. 511-536). Cambridge University Press.

Chantuma, P. (2007). *Para rubber academic data 2007*. Rubber Research Institute, Department of Agriculture, Thailand.

Chantuma, P. (2008). Effects on the yield of rubber trees when tapping below the standard size. *Rubber Journal*, *29*(2), 32-47.

Chantuma, P. (2020). Increasing the productivity and income of farmers in Trang Province (Thailand) from rubber plantations according to the GAP standards. *Rubber Journal*, *41*(2), 2–12.

Chiarawipa, R. (2019). Rubber-based inter cropping system in Southern Thailand: Its constraints and planting patterns on sustainable productivity. *King Mongkut's Agricultural Journal*, *37*(1), 179-189.

Gohet, E., Lacote, R., Leconte, A., Chapuset, T., Rivano, R., & Chambon, B. (2016, November 21-22). Improving rubber smallholdings productivity and resilience through adoption of good agricultural practices [Conference presentation]. *CRRI IRRDB Workshop on Transfer of Technology "Good Agricultural Practices, Reduced Wastages, Improved Quality, Productivity and Profitability"* at Phnom Penh, Cambodia. https://agris.fao.org/agris-search/search.do?recordID=FR2019134326

Hong Van, N. T., Hoa Thien, H., & Nguyen, V. T. (2001). *Application of fertiliser recommendation followed nutrient diagnosis method for immature rubber on basaltic soil of the southeast region. Scientific Achievement in the Year 2000*. Rubber Research Institute of Vietnam.

Kangpisadan, N. (2006). Fertilisers are recommended for rubber plantations. *Rubber Journal*, *30*(3), 22-27.

International Organization for Standardization. (2005). *Natural rubber latex concentrate - Determination of dry rubber* (ISO Standard No.126.2005). https://www.iso.org/standard/35176.html

International Organization for Standardization. (2014). *Latex, rubber- Determination of total solids content* (ISO Standard No.124.2014). https://www.iso.org/standard/61884.html

International Organization for Standardization. (2017).

ISO 2004: 2017 Natural rubber latex concentrate - Centrifuged or creamed, ammonia preserved types — Specifications. (ISO Standard No. 2004.2017). https://www.iso.org/standard/70281.html

International Organization for Standardization. (2020). *Rubber latex, natural, concentrate - Determination of volatile fatty* (ISO Standard No. 506.2020). https://www.iso.org/standard/77456.html

Kangpisadan, N. (2013). Soil and fertiliser management for sustainable rubber production. Academic documents. In *Sustainable management of rubber plantations* (pp. 26-32). Rubber Research Institute of Thailand, Department of Agriculture.

Kanjanavisut, K. (2020). COVID-19 increased global demand for medical gloves. EIC indicates that Malaysia has gained more export than Thailand. *Siam Commercial Bank (SCB) Economic Intelligence Center*. https://www.scbeic.com/en/detail/product/6857

Norsuwan, T., Kularb, U., Thakoon, P., Thanit, S., Rattanaphon, C., Pongsakorn, S., Ekachai, Y., Vipavee, S., Nadchawan, C., & Thewin, K. (2021). Urban Agriculture and BCG Economic Mode. *Agricultural Research and Promotion Journal*, *38*(3), 100-116.

Ministry of Natural Resources and Environment of Thailand. (2016). *Regarding the standard for controlling wastewater from industrial factories, Industrial estates, and industrial areas*. Government Gazette (Vol. 133). https://www.pcd.go.th/laws/4378

Pakchareon, H. (2012, March 2). *Sampling selection techniques* [Workshop project]. National Statistical Office. Bangkok, Thailand. http://service.nso.go.th/nso/nsopublish/Toneminute/files/55/0203-5.pdf

Phanmai, J. (2021, April 24). *Rubber innovation towards the world industry* [Conference presentation]. Rubber group committee of the polymer society of Thailand. Bangkok, Thailand.

Phaechana, P., Boonpiyathida, K., & Supinya, C. (2011). Harvesting of latex products. *Rubber Journal*, *32*(3), 35-42.

Poonlabthawee, K. (1996). *Statistics for research*. Department of Technology Education, King Mongkut's Institute of Technology, Thailand.

Riches, J. P., & Gooding E. G. B. (1952). Studies in the physiology of latex. I. Latex flow on tapping – Theoretical considerations. *New Phytologist*, *51*(1). https://nph.onlinelibrary.wiley.com/doi/pdf/10.1111/j.1469-8137.1952.tb06112.x

Rubber Authority of Thailand, (2022). *Rubber enterprise plan of Thailand 2021-2027.* RAOT. https://www.raot.co.th/download/plan/enterprise/enterprise_plan_(65)64-70.pdf

Rubber Research Institute of Thailand. (2020). *Good agricultural practices for rubber*. Rubber Authority of Thailand.

Santipanusopon, S. & Riyajana, Sa-Ad. (2009). Effect of field natural rubber latex with different ammonia contents and storage period on physical properties of latex concentrate, stability of skim latex and dipped film. *Physics Procedia*, *2*,127-134.

Schreinemachers, P., Iven, S., Prasnee, T., Pakakrong, M. W., Andreas, N., Suthathip, R., Walaya, S., & Christian, G. (2012). Can public GAP standards reduce agricultural pesticide use? The case of fruit and vegetable farming in Northern Thailand. *Journal of Agriculture, Food and Human values Society*, *29*, 519-529. https://link.springer.com/article/10.1007/s10460-012-9378-6

Thailand Agriculture Standard. (2019). *Good agricultural practices for rubber to produce fresh latex* (TAS No. 5908.2019). http://rubber.oie.go.th/box/ELib_Document/7040/เกษตร137.pdf

Thailand Agriculture Standard. (2021). *Good manufacturing practices for latex collection Centres* (TAS No. 5911.2021). https://www.acfs.go.th/files/files/commodity-standard/20210616111528_219294.pdf

Tassanakul, P. (2019). Good manufacturing practice for latex collection center. *Rubber Journal*, *40*(3), 43-52.

Tassanakul, P. (2021a). Production of premium grade thin brown crepe from high-quality cup lumps. *Journal of Science Innovation for Sustainable Development*, *3*(1), 1-14. https://ph01-ohno.tci-thaijo.org/index.php/JSISD/article/view/243536

Tassanakul, P. (2021b, May 27-28). Management of Rubber Plantation According to GAP and Air-dried sheet production According to GMP of Agricultural Learning Center of General Prem Tinsulanonda Statesman Foundation for Sustainable Development [Conference presentation]. *The 6th National Conference and the 2nd International Conference on Informatics, Agriculture, Management Business Administration Engineering, Sciences and Technology, Thailand*.