Malaysia

FY2021 Ex-Post Evaluation Report of Technical Cooperation Project (SATREPS)[1]

"Project on Promotion of Green Economy with Palm Oil Industry for Biodiversity Conservation"

External Evaluator: Takako Haraguchi, i2i Communication, Ltd.

0. Summary

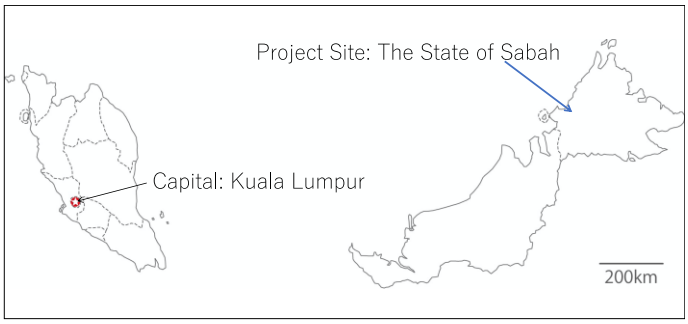
This project attempted, primarily in the State of Sabah, to develop proposals for transforming the palm oil industry into a green industry and creating new business opportunities and share these technologies with potential users, by developing technologies for the effective use of surplus biomass (palm biomass) generated in palm oil mills, thereby contributing to the preservation of biodiversity through greater commercialization of these proposals. The relevance of these objectives is high as they are consistent with the development policies of Malaysia and Sabah, their development needs, and Japanese aid policies. Several technologies for the use of palm biomass were developed as a result of joint research under this project, which were then organized as business models, including investment plans, attracting the interest of companies and other related parties. The project also developed a method for assessing biodiversity.

Research in these areas has generated a number of research publications and graduate degrees, thus achieving the project purpose. This evaluation determines that the project achieved its overall goal at a limited level because the government of the State of Sabah (Sabah government) did not consider the use of the research results, and the application of the business models in their entirety failed to take place. However, it is commendable that related research has continued and expanded, and certain individual technologies have been socially implemented. Therefore, the effectiveness and impact of the project are high. Although the project period was as planned, the project cost slightly exceeded the plan. Therefore, the efficiency of the project is fair. The sustainability of the project has been achieved at research institutions. However, as mentioned above, the institutional and organizational aspect remained undeveloped in the Sabah government. Considering these results, the sustainability of the project effects is fair.

In light of the above, this project is evaluated to be satisfactory.

[1] Science and Technology Research Partnership for Sustainable Development

1. Project Description



Project Location

Compost (fertilizer) production from oil palms' empty fruit bunches (EFB)[2] and palm oil mill effluent (POME)
(State of Terengganu)

1.1 Background

The palm oil industry is the main industry in Sabah, and the impact on water quality from pesticides used in oil palm plantations and the treated water discharged from oil mills that operate with outdated wastewater treatment systems has become a problem. In particular, there were concerns about the impact on biodiversity in the Kinabatangan-Segama River Basin, which embraces a number of forest reserves and wildlife sanctuaries, including a Ramsar site, providing habitats for rare wildlife.

The Kyushu Institute of Technology and the University of Putra Malaysia (Universiti Putra Malaysia; UPM) was jointly developing technology for manufacturing resin composite materials (biocomposites) made from biomass. In Malaysia, since palm oil mills generate a large amount of palm biomass of stable quality throughout the year, it was hoped that the development of technologies for effective uses of surplus biomass would create new business opportunities and industries while reducing palm oil-derived pollutants. In addition, the Japan International Cooperation Agency (JICA) was also working with the government of the State of Sabah and the University of Malaysia of Sabah (Universiti Malaysia Sabah; UMS) to implement a series of Technical Cooperation projects aimed at promoting biodiversity and ecosystem conservation in the state, including the Technical Cooperation Programme for Bornean Biodiversity and Ecosystems Conservation in Sabah, Malaysia (BBEC) (Phase 1: 2002-2007, Phase 2: 2007-2012) and the Project on Sustainable Development for Biodiversity and Ecosystems Conservation in Sabah (SDBEC) (2013-2017). Through these collaborations, the importance of sustainable development for biodiversity conservation was recognized to an even greater degree.

[2] Empty fruit bunches are the residual substance after the fruit is removed from the bunches.

1.2 Project Outline

Overall Goal		A green economy is promoted in the palm oil industry of Malaysia, which will contribute to biodiversity recovery through zero-discharge technologies[3] in relevant areas in Sabah, including Kinabatangan.
Project Purpose		Innovative knowledge and viable technologies[4] for business models are developed and shared positively among the potential users for the transformation of the palm oil industry into a sustainable green industry.[5]
Outputs	Output 1	The effectiveness of zero-discharge is ensured through energy efficiency improvements resulting in surplus biomass and excess energy at showcase facilities of zero-discharge established at an oil mill.
	Output 2	The viability of a business model is verified through the proposed zero-discharge and creation of new industry from surplus biomass and excess energy.
	Output 3	Innovative research on the effective utilization of palm biomass and energy is pursued to reduce the environmental burden caused by palm oil processing.
	Output 4	The validity of a business model and the research results are shared extensively and recognized within the Sabah government and domestic/international investors and firms.
Total cost (Japanese Side)		336 million yen

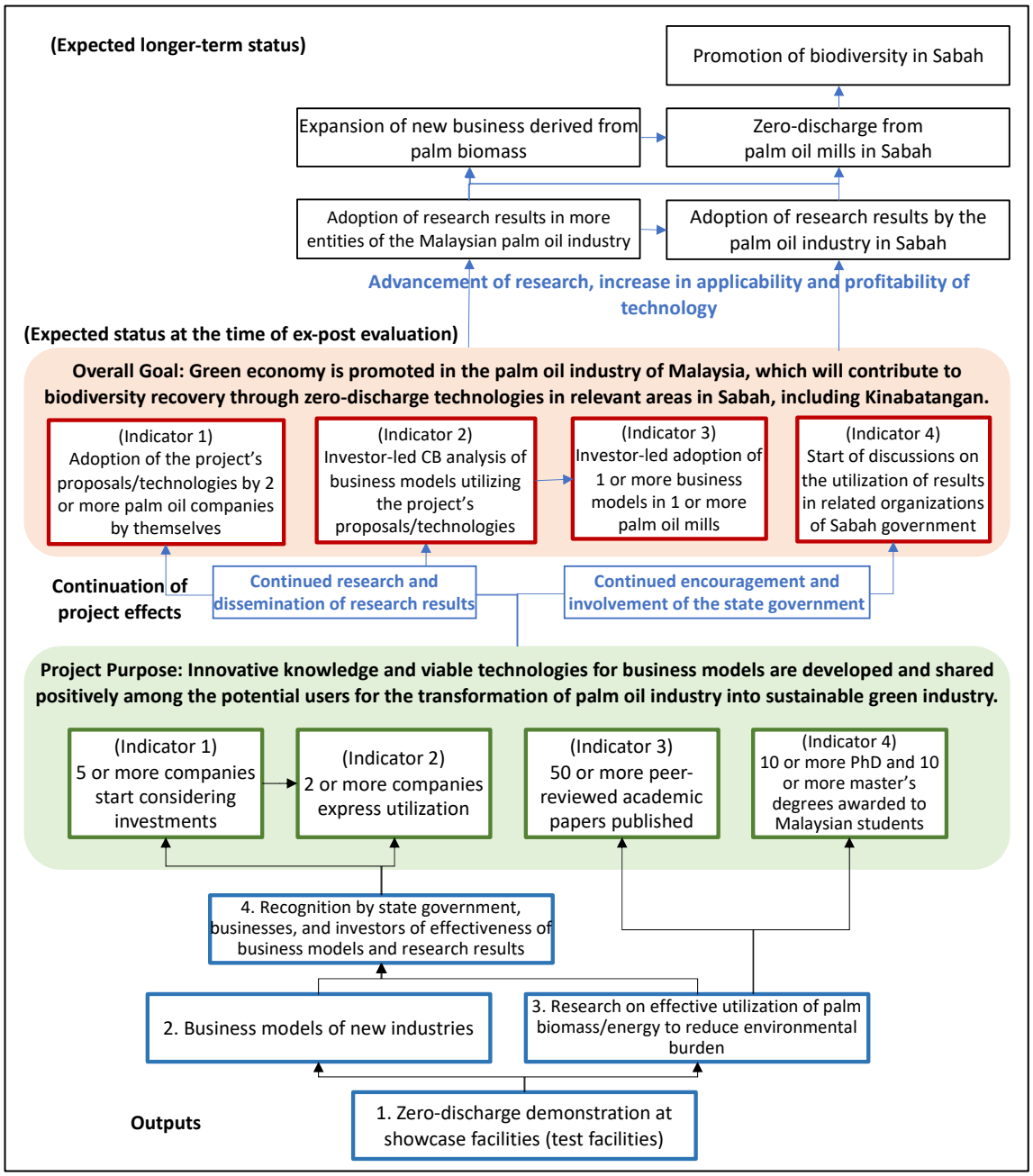
[3] According to the ex-ante evaluation sheet for the project, "zero discharge" refers to all by-products from the oil mill being converted into useful biomass, energy, or recycled water that is either valuable or tradable as a result of improved energy efficiency and resource use in the palm oil production process. The concentrations of sulfur oxides, nitrogen oxides, and fine particulate matter emitted are kept below government regulation levels, and the methane gas generated from the biomass is recovered for use as energy.

[4] According to the ex-ante evaluation sheet, "innovative knowledge and viable technologies" refers to the entire research results with respect to technologies for producing bio-composites, bio-plastic materials, micro-fibers, activated carbon, fertilizers, and other useful materials using surplus energy, palm biomass, superheated steam, and methane gas from oil mills. It also includes information on new business models and investment proposals for the palm oil industry using the idea and method of zero discharge.

[5] According to the ex-ante evaluation sheet, a "sustainable green industry" refers to an industry that is sustainable from environmental, social, and financial perspectives.

Period of Cooperation	November 2013 – November 2017
Target Area	State of Sabah
Implementing Agency	Universiti Putra Malaysia (UPM) Universiti Malaysia Sabah (UMS) Natural Resources Office (NRO) of the State of Sabah
Other Relevant Agencies/ Organizations	–
Consultant/ Organization in Japan	Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology National Institute of Advanced Industrial Science and Technology (AIST) Faculty of Agriculture, Kyushu University
Related Projects	Technical Cooperation • Technical Cooperation Programme for Bornean Biodiversity and Ecosystems Conservation in Sabah, Malaysia (BBEC) (Phase 1: 2002-2007; Phase 2: 2007-2012) • Project on Sustainable Development for Biodiversity and Ecosystems Conservation in Sabah (SDBEC) (2013-2017) • Training Program for Biomass Carbonization by the Yamasen Pool-type Oven (JICA Partnership Program) (2012-2015) • Verification Survey with the Private Sector for Disseminating Japanese Technologies for Improvement of Wastewater Treatment System and Recycling of Resources at Palm Oil Mills in Malaysia (SDG Business Supporting Survey Program) (2015-2017) Other related projects • Japan Science and Technology Agency (JST), “Fiscal Year 2008 SATREPS Draft Proposal (Plan B)” (2016) • JST, “Commercialization of Biodegradable Nano Composites in Malaysia” (Accelerating Social Implementation for SDGs Achievement; hereinafter referred to as “aXis Project”) (2020-2022)

The evaluator summarized the logic model of the project as shown in the figure below. The portion between “Outputs” and “Overall Goal” shows the objectives and indicators that were expected to be achieved by the time of ex-post evaluation (the final plan after several modifications during the project implementation) based on reports from JICA and JST, and the area above them summarizes the effects that were expected to manifest over the longer term based on reports and interviews with the implementing agencies and other relevant organizations. The expected final impact of the project has been the conservation of biodiversity in Sabah. However, since the expansion of research and the use of research results, and the development of a green economy in the palm oil industry are expected to take place not only in Sabah but also in other regions of Malaysia, the ex-post evaluation is conducted assuming the logic that these developments could also lead to the use of research outcomes in Sabah.



Sources: Created based on JICA Terminal Evaluation Report (2017), JST Final Report (2018), interviews with the implementing agencies and other related parties

Figure 1: Logic model for the project

The division of roles among the implementing agencies and Japanese research institutes for each project output was as follows. For Output 1, the Kyushu Institute of Technology was in charge of all activities on the Japanese side, UPM was in charge of the operation and maintenance of the showcase facility (test facility) for the technology demonstration, and UMS was in charge of analyzing the effluent. For Output 2, the Kyushu Institute of Technology was in charge of developing a business model for the

utilization of the research results, and other institutions cooperated with it. For Output 3, the Kyushu Institute of Technology (general), the AIST (saccharification[6]), and Kyushu University (biodiversity) were responsible for their respective research topics, with UPM and UMS participating in joint research mainly related to biomass utilization and biodiversity, respectively. With respect to Output 4, all institutions participated and shared the research results.

1.3 Outline of the Terminal Evaluation

1.3.1 Achievement Status of Project Purpose at the Terminal Evaluation

The evaluation result was that the project mostly achieved the project purpose. In particular, the evaluation cited that "the outputs exceeded expectations" in terms of research results and personnel development.

1.3.2 Achievement Status of Overall Goal at the Terminal Evaluation (Including other impacts.)

With respect to the overall goal at the time of the terminal evaluation, the evaluation recommended that the overall goal be modified, determining that: "It would be difficult to achieve the overall goal within three years because the indicators are difficult to achieve with limited availability of resources for social implementation. The overall goal also needs to be modified so that the technologies developed in the project can be disseminated more broadly." In response to the recommendation, the overall goal and indicators were changed to the ones that would not deviate from the project purpose (as described in Section 1.2 ("Project Description") above and were formally agreed upon by all parties.[7]

1.3.3 Recommendations from the Terminal Evaluation

The recommendations were as follows, all of which were addressed within the project period.

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[6] Saccharification is the process of obtaining sugars from biomass that can be used as raw materials for chemicals.

[7] The overall goal at the time of the terminal evaluation was, "Green economy is promoted in the palm oil industry of Malaysia, which will contribute to biodiversity recovery through the reduction of pollutants from palm oil effluent in relevant areas in Sabah, including Kinabatangan." (The underlined words have been revised.) Among the indicators, "The technologies proposed by or derived from the project are adopted in at least ten palm oil companies in their palm oil mills by themselves" was removed. This ex-post evaluation is conducted using the revised overall goal.

- Revisions of the overall goal and its indicators and important assumptions: Formal revisions were agreed upon by parties in both countries.
- Modification of the proposed business models and investment plans: A proposal with a lower level of initial investment was added.
- Incorporation of research results into policy dialogue: Briefings were provided to relevant ministries and agencies.
- Reaching out to potential investors through seminars, available platforms, and mass media: Seminars were conducted.
- Meeting the smoke emission regulations (carbon monoxide (CO) and particulates (PM10)) for the carbonization furnace at the showcase facility: The standards were met after conducting certain improvement works.
- Finalization of the management plan for the showcase facility (by the end of this project on the Malaysian side (August 2018)): Completed.

2. Outline of the Evaluation Study

2.1 External Evaluator

Takako Haraguchi, i2i Communication, Ltd.

2.2 Duration of Evaluation Study

This ex-post evaluation study was conducted with the following schedule.

Duration of the Study: July 2021 – June 2022

Duration of the Field Study: December 2021 – February 2022 (conducted remotely from Japan[8])

3. Results of the Evaluation (Overall Rating: B[9])

3.1 Relevance (Rating: ③[10])

3.1.1 Consistency with the Development Plan of Malaysia

The consistency of the project with the development plan was high both at the time of the ex-ante evaluation and the time of the project completion.

[8] Owing to the new coronavirus pandemic, a local consultant conducted interviews with the implementing agencies and related organizations and made site visits under the direction of the ex-post evaluator.
[9] A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory
[10] ③: High, ②: Fair, ①: Low

The development plans of the central government and the Sabah State Government (see the table below) seek to make effective use of palm biomass and transform the palm oil industry into a green industry.

The Malaysian government has also developed a certification system for the sustainable palm oil industry. In April 2004, the Roundtable on Sustainable Palm Oil (RSPO), a private international certification framework (headquartered in Geneva, with the Secretariat in Kuala Lumpur), was established to develop a certification system for palm oil production and distribution. In addition to joining the RSPO, the Malaysian government launched the Malaysian Sustainable Palm Oil (MSPO) system in 2013 to encourage palm oil companies to obtain these certifications.

Table 1: Development policies relevant to this project

At the time of ex-ante evaluation	At the time of project completion
National development policies *Tenth Malaysia Plan* (2011-2015) By recognizing the palm oil industry as one of the 12 key national economic sectors, it sought not just to increase the total production but also to improve productivity and production efficiency. *National Biomass Strategy 2020* (established in 2010) It promotes policies, including a shift from the incineration of biomass to the use of biomass.	National development policies *Eleventh Malaysia Plan* (2016-2020) One of the priority areas is the "adoption of sustainable consumption and production concept." One of the strategies it promotes is to invest in waste as a resource, including the use of biomass for power generation. *National Biomass Strategy 2020* (established in 2010) Same as left (effective at the time of project completion)
Sabah's development policies *Direction for Development and Progress of Sabah* (Halatuju Pembangunan dan Kemajuan Negeri Sabah) (2004) It discusses the preservation of specific areas for the conservation of natural resources that can support healthy ecosystems while achieving economic development. *Sabah Biodiversity Strategy* (2012-2022) Awaiting approval in the Cabinet meeting. The formulation of the plan was assisted in BBEC Phase 2, a JICA Technical Cooperation project, and a draft was completed.	Sabah's development policies *Sabah Long-Term Strategic Action Plan* (2016-2035) It specifies that the development in Sabah be promoted from economic, social, and environmental perspectives. *Sabah Biodiversity Strategy* (2012-2022) Same as left. It seeks to transform the palm oil industry into a sustainable one to reduce pressure on biodiversity. *Sabah Biomass Industry Development Plan* (2015-2020) Based on the *National Biomass Strategy 2020*, it formulates plans for monitoring the balance of biomass generation and use in each production area and establishing an efficient utilization mechanism.

Sources: Ex-ante evaluation sheet, JICA Terminal Evaluation Report, documents mentioned in the table

3.1.2 Consistency with the Development Needs of Malaysia

The project was consistent with the development needs of Malaysia and Sabah both at the time of the ex-ante evaluation and the time of the project completion. Because the scale of the palm oil industry in Sabah remained constant throughout the project implementation period (see the table below), the need to reduce environmental burdens from palm oil mills and to increase the revenues from the palm oil industry continued to exist. In addition, the Malaysian Palm Oil Board, the NRO, Sabah, and other related agencies were paying close attention to the environmental impact of wastewater from palm oil mills and the state of biodiversity in the Kinabatangan and Segama River basins, as evidenced by project-related materials and documents from these agencies.

Table 2: Statistics for palm oil production in Malaysia and Sabah

	2011	2017
Oil palm plantation area in the country (thousand ha)	5,000	5,811
Within Sabah (thousand ha)	1,430	1,547
Oil palm production in the country (kt)	18,912	19,919
Within Sabah (kt)	5,840	5,215
Sabah's palm oil-related export earnings (million ringgit)	13,800	15,700
Percentage within Sabah's export earnings (%)	40	44

Source: Malaysian Palm Oil Board statistics

3.1.3 Consistency with Japan's ODA Policy

The consistency with Japan's ODA policy at the time of the ex-ante evaluation was high. According to the *Country Assistance Policy for Malaysia* (April 2012), Japan identified "supporting a balanced development towards Malaysia becoming a high-income nation" as one of the priority areas, which included the promotion of environment-related businesses related to the development issue of "promoting the sophistication of the economy." Thus, Japan's assistance policy supported measures not only for environmental conservation but also for the promotion of a sophisticated and high-value-adding economy.

In light of the above, this project was highly relevant to the country's development plan and development needs, as well as Japan's ODA policy. Therefore, its relevance is high.

3.2 Effectiveness and Impacts[11] (Rating: ③)

3.2.1 Effectiveness

3.2.1.1 Project Output

Output 1: The effectiveness of zero-discharge is ensured through energy efficiency improvement resulting in surplus biomass and excess energy at showcase facilities of zero-discharge established at an oil mill.
Output 2: Viability of business model is verified through the proposed zero-discharge and creation of new industry from surplus biomass and excess energy.
Output 3: The innovative research is pursued on the effective utilization of palm biomass and energy for the reduction of environmental burden caused by palm oil processing.
Output 4: Validity of the business model and the research results are shared extensively and recognized within the Sabah government and domestic/international investors and firms.

In the joint research of this project, various joint studies were conducted on the effective use of palm biomass, especially empty fruit bunches (EFB), mesocarp fiber (MF) (the pulpy part of the fruit after oil extraction), and palm oil mill effluent (POME) generated at palm oil mills,[12] and its impact on biodiversity. With respect to the demonstration of zero-discharge (Output 1), a showcase facility was installed at a palm oil mill located in Keningau District in western Sabah to demonstrate a POME treatment system, carbonization furnace, and composting equipment. As individual research results, including those technologies (Output 3), the following technologies were mainly developed (the number in parentheses is the indicator number for Output 3).

- Biocompost/biochar (bio-based fertilizer and charcoal) (Indicator 11):

  Methods were developed to recover organic matters from solid biomass by superheated steam[13] treatment (using surplus steam generated in the oil palm treatment process prior to oil extraction) and to produce compost and charcoal from POME and EFB. In addition, a high-performance compost production method using microorganisms was developed.

- Biocomposites (bio-based resin composites) (Indicators 4-10):

[11] Sub-rating for Effectiveness is to be put with consideration of Impact.
[12] In the common palm oil production process, oil palm fruit bunches are boiled, then separated into fruit and empty bunches, and, finally, the oil is pressed from the fruit. The fruit is separated into palm oil and mesocarp fiber during pressing, and the mesocarp fibers are consumed as boiler fuel.
[13] Superheated steam is steam heated to a temperature above the boiling point.

A technology for producing cellulose nanofibers from EFB and MF and a method for producing nanocomposites[14] using such cellulose nanofibers as a raw material were developed.

- Biodiversity (Indicators 1-3):

  A simple method was developed to monitor the effects of treated wastewater from palm oil mills on the microbial ecology of the rivers and streams into which such treated wastewater drains. A method for monitoring biodiversity through microbial diversity monitoring was developed. The key microorganisms that play a role in each step of the POME treatment were identified. Characteristics of soil microorganisms in natural forests, secondary forests, and plantations were identified.

- Wastewater treatment:

  A method for clarification of POME through distillation using surplus steam was developed.

In addition, one of the unique aspects of this project is that its project design was strongly oriented towards social implementation as well as research activities. The project developed several different versions of the business plan, *Energy Supply and Environmental Conservation Business Using Surplus Palm Biomass*, which combined the generation of revenues through the sale and supply of "green power" generated by increasing the efficiency of biomass power generation[15] (using solid palm biomass as fuel) and the introduction of biogas power generation (using methane gas recovered from POME), the development and promotion of new "green businesses" (the production of chemical products, fuels, compost, and other value-added products, plant factories using surplus electricity, eco-tourism, etc.), and the clarification of wastewater using steam (Output 2), and shared the plan with Japanese and Malaysian companies, research institutions, and government agencies at workshops and seminars (Output 4).

3.2.1.2 Achievement of Project Purpose

The following indicators for measuring the achievement of the project purpose were attained: interest among potential users in the technologies and business

[14] Nanocomposites are composite materials in which particles on the order of nanometers (1-100 nanometers) are kneaded into the material.

[15] In general, palm oil mills generate their own electricity by burning the palm biomass generated by the mill. As part of the research for Output 2, it was identified that this practice was inefficient.

models developed under the project (Indicators 1 and 2), research (Indicator 3), and human resource development (Indicator 4) (see the table below). In particular, with respect to research and human resource development, the number of research articles and the number of individuals who were awarded PhD or master's degrees significantly exceeded the target numbers. The JST also found these achievements satisfactory. The achievement of the results that exceeded the plan may be attributable to the high visibility and importance of the research themes and the fact that there was an accumulation of joint research and networking prior to this project.

Table 3: Achievement of Project Purpose

Project Purpose	Indicator	Actual
Project Purpose: Innovative knowledge and viable technologies for business models are developed and shared positively among the potential users for the transformation of the palm oil industry into a sustainable green industry.	1) At least five firms or investors start considering actual investments based on the business model and model investment plan.	Achieved. The project team spoke with a number of companies. Of these, the following 13 companies that continued to discuss their plans count towards this indicator. • A Japanese company that conducted joint experiments on wastewater treatment under the JICA SDGs Business Supporting Survey Program[16] • A Japanese company that was conducting research on hydrothermal processing of palm biomass • A Japanese company that had entered into a research service agreement with UPM • Nine Japanese companies that formed a consortium and applied to the JST's SDGs Business Support Program using the Outcomes of SATREPS (Although the consortium was not selected, it counts towards this indicator because it considered investments.) • A Palm oil mill of a Malaysian company in Terengganu
	2) At least two firms express their willingness to apply the technologies and research results that are generated from Output 3.	Achieved. Of the companies that qualified for Indicator 1 above, 11 companies expressed their willingness to apply the technologies and research results generated from the project.
	3) At least 50 research articles are prepared on the related subjects/topics and published.	Achieved. A total of 125 papers were published, including 75 peer-reviewed papers co-authored between Japan and Malaysia and 50 peer-reviewed papers authored in one of these two countries.
	4) At least 10 PhD and 10 master's degrees are awarded to Malaysian students who studied the related subjects/topics.	Achieved. Sixteen individuals earned PhD degrees at the Kyushu Institute of Technology, UPM, and Kyushu University, and all of them were appointed to research positions. In addition, two students received Japanese government-sponsored SATREPS scholarships to study in Japan and earned PhD degrees. The number of individuals who earned master's degrees was higher. (However, it was difficult to count the number of master's degrees when interviewed at the time of the post-evaluation).

Sources: JICA Terminal Evaluation Report (2017), JST Final Report (2018), interviews with UPM and USM

[16] *Verification Survey with the Private Sector for Disseminating Japanese Technologies for Improvement of Wastewater Treatment System and Recycling of Resources at Palm Oil Mills in Malaysia* (2015-2017)

Therefore, the project achieved its purpose.

3.2.2 Impact

3.2.2.1 Achievement of Overall Goal

The overall goal of the project was to contribute to the conservation of biodiversity through the reduction of environmental burdens by having the research results and business models of the project adopted by the palm oil industry (i.e., by promoting a green economy). At the time of the ex-post evaluation, of the four indicators that had been set, Indicators 1-3 were partially achieved, while Indicator 4 was not achieved. (See the table below.)

Indicators 1-3 (the use of research results by palm oil mills and investors) were not realized as a business-model package, nor in Sabah. However, individual technologies, especially compost production and nanocomposite production (more precisely, the production of cellulose nanofibers, the raw material for nanocomposites), were realized in Peninsular Malaysia. Considering the nature of the indicators, both of these results clearly show that the results of the project are being utilized.

Factors that facilitated such achievements include the fact that these research topics were of high importance, that the accumulation of joint research prior to the project allowed the project to develop and share individual technologies that could be used as soon as the project was completed, and that UPM co-researchers were willing to apply technologies, including by creating startups. In addition, it appears that the fact that the project had clearly set the development of business models as one of the indicators for the overall goal also helped the participants to stay conscious of the goals of the joint research.

Obstacles include the fact that the profitability of implementing business models as packages was inadequate owing to high facility costs[17] and that the perception of sustainable development among palm oil mills was not high enough to consider new investments. The interviews with the universities and the NRO indicated that no companies had indicated their willingness to adopt the business models (in Sabah, no companies had indicated their willingness to adopt individual technologies, either). Some of the reasons included “the mills are already complying with environmental regulations, and they are not interested in

[17] The return on initial investment calculated in the project ranged from 0.7% to 2.1% (over 20 years), depending on the model.

additional environmental measures" and "many of the palm oil businesses in Sabah are small and medium-sized businesses, and they are focused on profitability or cannot afford to invest in going green," and "the business models are too far ahead of their time." Although many companies showed interest when the research results were shared with them during the project implementation, it appears that companies did not find enough incentive to take action to commercialize these research results. In addition, because the showcase facilities in Sabah were removed after the project completion, there was no longer a venue for demonstrating technologies.[18] The research results have also not been disseminated actively.

However, compared to the time of project completion, efforts to promote a sustainable palm oil industry, as represented by RSPO/MSPO certification,[19] have made further progress by the time of the ex-post evaluation. As a result, the need for palm biomass utilization has also increased in Sabah. In addition, ongoing research since the completion of this project has led to the development of lower-cost or simpler technologies. New research and development in the field of nanocomposites by UPM and Malaysian companies are also underway. (See the box below for the research status at the time of the post-evaluation.) Furthermore, since there are also palm oil companies from Peninsular Malaysia operating in Sabah, if those companies find such developed technology feasible after applying them in Peninsular Malaysia, they may also apply these technologies in Sabah.

[18] This measure was taken because the plant was privately owned. According to several sources, the main business of the plant's owner is dairy farming, and it is believed that the owner had little incentive to make a similar capital investment again at at the cost of the plant. At the time of the ex-ante evaluation, the showcase facilities were to be installed at a palm oil mill affiliated with the state government near the Kinabatangan River in the eastern part of Sabah, where the research team had been conducting joint research prior to this project. However, it should be noted that owing to the deterioration of the security situation in the eastern part of the state after the commencement of the project, the installation location was changed to the private factory in the western part of Sabah.

With respect to the wastewater treatment system of the showcase facility, the tank has been disposed of, and the effluent treatment equipment has been transported to the UPM's biorefinery plant (Selangor), but the equipment is being stored there owing to the unavailability of a budget to rebuild the entire system again. Composting equipment (forklifts, skid loaders, compost turners) is being used at the same UPM plant. For the carbonization furnace, only its construction was completed under the project, and the equipment was procured by the Kyushu Institute of Technology. Certain equipment (the chimney part) is stored at the UPM Bintulu Campus (Sarawak).

[19] The RSPO certification required for palm oil mills is called the "Principles and Criteria (P&C) certification," whose standards include environmental protection through the use of biomass. At the time of the ex-post evaluation, 140 of the 449 palm oil mills in Malaysia are RSPO certified. (The number of plants is as of January 2022 (Malaysian Palm Oil Board); the number of certified plants is based on the date on the RSPO website as of the end of February 2022.)

The MSPO certification became mandatory as of January 1, 2020, and by the end of that year, 96% of Malaysian palm oil mills were certified (March 9, 2001, article in The Edge, "86.4% of Malaysia's total licensed oil palm planted area MSPO-certified, says MPOB").

Therefore, there is a good possibility that the research results will be used in Sabah in the future.

Indicator 4 (consideration within the Sabah government on the use of research results) failed to take place. The NRO, the implementing agency on the Malaysian side, explained that it was responsible for environmental conservation and was not in a position to promote specific palm biomass utilization technologies. It also appears that the project itself has been completed without sufficient discussion of the division of roles within the state government. In this regard, the transition of the project's design may have been a contributing factor. That is, at the time of the ex-ante evaluation, the NRO was regarded as the focal agency of the Sabah government, with other agencies designed to cooperate as needed. However, in the process of changing the project plan during the implementation of the project, "Consideration within the Sabah government on the use of research results" was changed from a project-purpose indicator to an overall-goal indicator.[20] This may have created a situation where the discussion within the government was no longer regarded as something that should be done before the project completion, leading to the lack of actions to achieve this indicator. One of the recommendations made at the time of the terminal evaluation was the "incorporation of research results into policy dialogue," and, in fact, additional explanations were provided by the project to the state government, but it is presumed that this did not lead to action in a situation where the division of roles was unclear. After the project completion, it appears that the universities or JICA did not encourage the Sabah government to take any action.

[20] After the start of the project, the project design matrix (PDM, a logical framework explaining a project design) was revised to align it with the JST's planning framework (consisting only of activities on the Japanese side), and some of the output-level indicators were changed to project-purpose level indicators. As a result, the consideration within the Sabah government was moved from the project-purpose level to the overall-goal level. In other words, the change does not appear to be a result of a review of how the Sabah government might be involved in the project.

Table 4: Achievement of Overall Goal

Overall Goal	Indicator	Actual
Overall Goal: Green economy is promoted in the palm oil industry of Malaysia, which will contribute to biodiversity recovery through zero-discharge technologies in relevant areas in Sabah, including Kinabatangan.	1) The technologies proposed by or derived from the Project are adapted in at least two palm oil companies in their palm oil mills by themselves.	Partially achieved. The following one company is counted towards this indicator. • Compost production from EFB and POME sludge at a palm oil mill of a Malaysian company in Terengganu. The biomass generated from oil palms harvested at six of the company's plantations is used to supply all of the fertilizer used on these plantations.
	2) Cost-benefit analysis of business models utilizing technologies based on the Project is carried out by the initiative of investors for potential commercialization.	Partially achieved. Although the three companies in Indicator 3 below are counted, this result is based on an analysis of individual technologies adopted rather than the business-model package. The status is unknown regarding the implementation of cost-benefit analysis in companies other than these three.
	3) At least one business model is adopted in at least one palm oil mill by the initiative of investors.	Partially achieved. The following three companies are counted, but the adoption took place at a single palm oil mill, and this was the adoption of individual technologies, not the adoption of a business-model package. • Compost production at the palm oil mill in Indicator 1 above. • A start-up company (in Selangor) established by the project's co-researchers at UPM manufactures and sells cellulose nanofibers (raw material for nanocomposites). The primary customers are researchers. • A Malaysian recycled pulp and paper manufacturing company (Pahang) is developing in collaboration with UPM a paper-based packaging material reinforced with cellulose nanofibers (research and development (R&D) stage).
	4) Policy discussions based on the results from the Project are started by relevant authorities in Sabah, Malaysia.	Not achieved. No discussion has taken place. The NRO, Sabah has not taken any specific action. The results of this project were taken up on the agenda of the Sabah Biomass Commission in 2018. However, after the chairman at that time stepped down, no specific action was taken on mainstreaming the technologies, nor was there any follow-up by UPM or JICA.

Sources: Interviews with UPM, UMS, NRO, and the Kyushu Institute of Technology

Status at the time of the ex-post evaluation of the research conducted under the project

Both UPM and UMS are continuing research in related fields, including joint research with the Kyushu Institute of Technology and Kyushu University, indicating the continuation and expansion of the project's results. The equipment provided under this project is also being used in such research. The key information obtained through interviews with universities for the ex-post evaluation and the number of papers published in specific fields after the project completion are as follows. At both UPM and UMS, the total number of degrees that have been awarded in these fields since the completion of the project is two PhD degrees and five master's degrees.

(1) Biocompost/biochar

UPM has a technical cooperation arrangement with a palm oil company in Trengganu and provides technologies for compost production from EFB and POME sludge at the company's oil mill. In

addition, UPM shares the data from this project with the research project on oil palm cultivation using palm biomass, which it has conducted outside of this project with the largest palm oil company in Malaysia. Research on biochar is also continuing at UPM's biorefinery plant in collaboration with Malaysian companies and with government funding.

UPM and Kyushu University are continuing research on the production of high-performance compost using microorganisms. The research has identified the microorganisms that inhibit the growth of phytopathogenic fungi that specifically infect oil palms. The researcher from Kyushu University is hoping to transition to experiments using actual oil palm trees in collaboration with Malaysian universities in the future. As of the time of the ex-post evaluation, conducting experiments involving international travel is not feasible owing to COVID-19, and international regulations concerning the transfer of biological resources prohibit the transportation of oil palm seedlings to Japan. For these reasons, Kyushu University is undertaking research on growth stimulation using different plants.

UPM has published five papers in the field of bio-composting/biochar since the completion of this project.

(2) Biocomposite

UPM and the Kyushu Institute of Technology are working on a JST aXis project, Commercialization of Biodegradable Nano Composites in Malaysia (2020-2022), in which cellulose nanofibers derived from palm biomass are kneaded into a biodegradable plastic to increase its strength and create a composite to identify its biodegradability and promote its commercialization. The technology developed in this SATREPS project had used expensive chemicals (ionic liquids) to produce cellulose nanofibers and a specially shaped twin-screw extruder to produce nanocomposites; since then, the Kyushu Institute of Technology has developed a method to produce nanofibers and nanocomposites at a lower cost with commercially available twin-screw extruders without using chemicals and adopted this method in the aXis project.

UPM and a Malaysian recycled pulp and paper manufacturing company (Pahang) are jointly developing a paper-based packaging material reinforced with cellulose nanofibers. In 2019, they received a research grant from the Malaysian government.

UPM has published 16 papers in the field of biocomposites since the completion of this project.

(3) Biodiversity

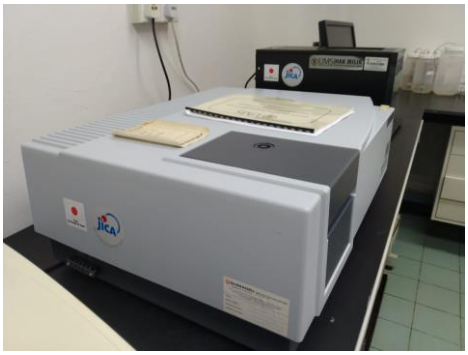
UMS and Kyushu University are continuing fixed-point observations in Sabah. UMS has also received a private grant to understand the impact of the sustainable use of oil palm resources on biodiversity. Some of the observations of the recovery of secondary forests could not be completed during the project period as these observations were time-consuming.

Based on the biodiversity in natural forests, secondary forests, and plantations identified through this project, UMS is considering research with Japanese universities on the production of chemicals using plants and other materials.

UPM and the Kyushu Institute of Technology are developing bioremediation technology based on the effects of treated wastewater from palm oil mills on microbial ecology, which was identified through this project.

UPM has published five papers in the field of biodiversity since the completion of this project. UMS has published five or more papers.

Cellulose nanofibers production (UPM)



A fluorescence spectrophotometer: used to monitor the impact of treated wastewater on influent rivers (UMS)

Thus, the project has achieved its overall goal at a limited level because the Sabah government has not started the examination of the use of research results, while the use in the palm oil industry has been realized with respect to certain individual technologies, and it is expected that they will be used in the State of Sabah in the future.

3.2.2.2 Other Positive and Negative Impacts

No negative impacts on the natural environment have been reported, and no resettlements and land acquisitions have occurred.[21] With respect to positive impacts on the natural environment, the project was expected to contribute to the conservation of the ecosystem in Sabah, but no tangible impacts have materialized yet. However, according to UPM and UMS, the application of the project's research results is expected to lead to the purification of the rivers by improving wastewater treatment at palm oil mills, acceleration of oil palm growth by using the POME sludge as fertilizer, waste reduction, and the restoration of biodiversity through these efforts.

As another positive impact, UMS has initiated new research for sustainable development based on the findings of this project. UMS reported that it had acquired knowledge on the business aspects of palm biomass use based on the research results as of the project completion and identified the biodiversity that existed in virgin oil palm forests, secondary forests, and plantations, citing that

[21] Along with the *JICA Guidelines for Environmental and Social Considerations* (April 2010), the project was determined to have minimal adverse impacts on the environment (Environmental Category "C"). For the showcase facilities installed at the existing palm oil mill site in Keningau District, the environmental consideration review conducted when the facilities were being designed concluded that an Environmental Impact Assessment (EIA) under Malaysian law was not required. During the project implementation, wastewater and flue gas were adjusted to meet Malaysian environmental standards.

these factors had enabled research projects with other Japanese universities on the creation of new business opportunities (such as chemical production) that utilize these resources. UMS was also the implementing agency in a series of JICA Technical Cooperation projects (2002-2017) aimed at biodiversity conservation. UMS has accumulated knowledge in sustainable development through the implementation of these projects,[22] and this has been further facilitated by this project.

This project has achieved the project purpose of developing technologies for business models to transform the palm oil industry into a green industry and sharing them with potential users. The overall goal of promoting a green economy in the palm oil industry is judged to have been achieved at a limited level because the Sabah government did not examine the use of the research results and the application of the business models in their entirety failed to take place. However, it is commendable that research on the use of palm biomass and biodiversity conservation has continued and expanded, and certain individual technologies have been socially implemented. Therefore, the effectiveness and impact of the project are high.

3.3 Efficiency (Rating: ②)

3.3.1 Inputs

Table 5: Inputs

Inputs	Plan	Actual (as of project completions)
(1) Experts	One Long-Term (coordinator) Short-term (chief advisor, chemical engineering, applied microbiology, organic chemistry, ecology, etc.)	2 Long-Term (coordinators) 14 Short-Term (chief advisors, environmental development, biomass utilization, microflora analysis methods, biodiversity, etc.)
(2) Trainees received	Training in Japan	Training in Japan: 24 persons

[22] According to UMS, as a result of the implementation of BBEC Phase 1 and Phase 2, UMS realized that biodiversity conservation would require the involvement of local residents; it achieved effective outcomes in the subsequent SDBEC by incorporating measures such as the improvement of livelihoods. To take it to the next level, UMS believed that the involvement of the industry would be necessary and regarded the use of palm biomass in this SATREPS project as a strategy to achieve it. Consequently, even though the research results related to the use of palm biomass have not been incorporated into Sabah's palm oil industry by the time of the ex-post evaluation, the research results have led to additional research.

Inputs	Plan	Actual (as of project completions)
(3) Equipment	Showcase facility (high-efficiency boiler and turbine systems, wastewater methane anaerobic treatment power generation systems, superheated steam generation and biomass processing equipment, etc.), large injection molding machines, etc.	Showcase facility (same as on the left),[23] large injection molding machines (twin-screw extruders), laboratory analyzers, vehicles, etc.
(4) Overseas Activity Cost	9 million yen	6 million yen (As of the end of March 2017) for vehicles, airfares, other travel expenses, etc.
Japanese Side Total Project Cost (JICA only)	323 million yen in total	336 million yen in total
Malaysian Side Total Project Cost	78 million yen in total	45 million yen in total (Actual expenses by August 2016)

Sources: Ex-ante evaluation sheet, JICA Terminal Evaluation Report, other documentation provided by JICA, JST Final Report.
Note: Amounts are rounded down to the nearest 1 million yen. The Malaysian Side Total Project Cost is converted at 1 ringgit ＝ 30.14 yen (average rate for the disbursement period).

3.3.1.1 Elements of Inputs

No particular problems were observed in the content, quantity, quality, or timing of inputs on both the Japanese and Malaysian sides. It is reported that despite the geographical constraints of multiple research sites scattered over a long distance – UPM located in Peninsular Malaysia, UMS in Kota Kinabalu, the capital of the State of Sabah, and the showcase facilities in Keningau District, which require more than three hours of driving from UMS, including rough roads – there was a resident coordinator stationed at UMS to promote collaboration and facilitate activities. The achievement of the outputs was likely to be facilitated by such coordination and the fact that the core members consisted of researchers from both countries who had been collaborating in research for many years, as well as counterparts in JICA assisted projects for biodiversity conservation in Sabah, namely, BBEC Phases 1 and 2, and SDBEC. Responding to the recommendation of the mid-term review on Output 2 (development of business models), a Japanese consultant was hired to assist in the development of business models, conduct a cost-benefit analysis, and formulate model investment plans based on the results of the analysis. The project had been unable to hire a business consultant because the project budget had been significantly reduced owing to drastic changes in exchange rates, but the funding it received from the JST, Fiscal Year 2008 SATREPS Draft Proposal (Plan B), allowed it do so.

[23] Plant design, cost estimation, and construction supervision were contracted by JICA to NJS Co. Ltd.

According to the terminal evaluation report, the 3 million ringgit (approximately 78 million yen) provided by the government for local activities on the Malaysian side was an unusually large amount for a research grant, and this commitment by the Malaysian side to this project has likely had positive impacts on the project.

3.3.1.2 Project Cost

As shown in the table above, the project cost (the share of the Japanese side excluding inputs by the JST) slightly exceeded the plan (104％ against the plan).

3.3.1.3 Project Period

The project period was as planned (100% against the plan), with both the planned and actual project periods being four years.

Although the project period was within the plan, the project cost exceeded the plan. Therefore, the efficiency of the project is fair.

3.4 Sustainability (Rating: ②)

3.4.1 Policy and Political Commitment for the Sustainability of Project Effects

There is a continued emphasis on the promotion of a green economy and the conservation of biodiversity in the development policies of Malaysia and Sabah described in Section 3.1 (“Relevance”) and their successive policies. First, the *Twelfth Malaysia Plan* (2021-2025) states that one of the three pillars of the Plan is the “pursuit of sustainability” to promote a green economy. The *Sabah Biodiversity Strategy* (2012-2022) and the *Sabah Long Term Strategic Action Plan* (2016-2035) have remained in effect since the time of project completion (the former is being updated as of the time of the ex-post evaluation). Furthermore, in line with the *Twelfth Malaysia Plan*, the *State of Sabah Development Plan (Sabah Maju Jaya Development Plan)* (2021-2025) has proposed, as a strategy for the manufacturing sector, to develop industries in which palm biomass would be used as raw material and establish the Sabah Palm Oil Advisory Committee (Penubuhan Majlis Penasihat Sawit Sabah).

Thus, policy and political commitment to the sustainability of project effects appear to be in place.

3.4.2 Institutional/Organizational Aspect for the Sustainability of Project Effects

The institutions/organizations necessary to sustain the effects of the project include those that promote the continuation of relevant research at research institutions and the use of the research results by the Sabah government.

First, with regard to research institutions, both UPM and UMS have established internationally recognized research infrastructure. In particular, an adequate system is in place at UPM, which is a research university ranked 28th in Asia and 132nd in the world in the 2021 Quacquarelli Symonds (QS) World University Rankings. UMS's Institute for Tropical Biology and Conservation has experience in implementing the previously mentioned Technical Cooperation projects and Third Country Training Program.[24] With respect to joint research with Japan, both UPM (with the Kyushu Institute of Technology and Kyushu University) and UMS (with Kyushu University) have continued it under research cooperation agreements. On both the Malaysian and Japanese sides, the core members of the project and the researchers trained through the project continue to be involved in related research. In addition, no issues have been found with the equipment provided by the project at both UPM and UMS, as they are subject to the same maintenance system as other research facilities and equipment.

With respect to the Sabah government, it was anticipated that the promotion of the social implementation of the research results would be reflected in its policy, but the division of roles within the government has not been defined, and the state government lacks a proper system for this purpose (as explained in Section 3.2.2.1 ("Achievement of Overall Goal") with respect to Indicator 4 for the overall goal).

Thus, the institutions/systems for the implementing agencies have been established in the research institutions but not in the Sabah government.

3.4.3 Technical Aspect for the Sustainability of Project Effects

With respect to research institutions, research team members at UPM and UMS (including researchers who earned their degrees through the project) continue to be involved in related research. The maintenance of the equipment provided by the project has been conducted properly. Information is shared through research papers and manuals, and the maintenance work is handled by a full-time technician.

With respect to the Sabah government, as mentioned above, it lacks a system for utilizing the research results, but according to the NRO, its participation in the

[24] Integrated Biodiversity and Ecosystem Conservation (2013-2015)

project has enabled it to gain knowledge on related technologies. This was also confirmed in the interviews with former counterparts.

Thus, the technical aspect has been established at the implementing agencies.

3.4.4 Financial Aspect for the Sustainability of Project Effects

With respect to research institutions, UPM and UMS maintain a stable financial situation and have secured research grants. The research budget is stable with grants from the Ministry of Higher Education, the Ministry of Science, Technology and Innovation, other public organizations, and private companies. The research grants UPM received in 2021 amounted to 49 million ringgit. UMS has secured research grants for biodiversity research, stably receiving approximately 1 million ringgit per year.

With respect to the Sabah government, it has set aside a budget for biodiversity conservation under the *State of Sabah Development Plan* mentioned above. However, there is no budget allocated for activities related to this project as no such activities have been conducted. It should be noted that this issue has not been caused by the state government; rather, it is attributable to the fact that, as described in Section 3.2.2.1 (“Achievement of Overall Goal”), the project completed before the division of roles could be adequately set up within the government.

Thus, the financial condition of the implementing agency is adequate in the research institutions but not in the Sabah government.

Some minor problems have been observed in terms of the institutional/organizational and financial aspects. Therefore, the sustainability of the project effects is fair.

4. Conclusion, Lessons Learned and Recommendations

4.1 Conclusion

This project attempted, primarily in the State of Sabah, to develop proposals for transforming the palm oil industry into a green industry and creating new business opportunities and share these technologies with potential users, by developing technologies for the effective use of surplus biomass (palm biomass) generated in palm oil mills, thereby contributing to the preservation of biodiversity through greater commercialization of these proposals. The relevance of these objectives is high as they are consistent with the development policies of Malaysia and Sabah, their development needs, and Japanese aid policies. Several technologies for the use of palm biomass were

developed as a result of joint research under this project, which were then organized as business models, including investment plans, attracting the interest of companies and other related parties. The project also developed a method for assessing biodiversity.

Research in these areas has generated a number of research publications and graduate degrees, thus achieving the project purpose. This evaluation determines that the project achieved its overall goal at a limited level because the government of the State of Sabah (Sabah government) did not consider the use of the research results, and the application of the business models in their entirety failed to take place. However, it is commendable that related research has continued and expanded, and certain individual technologies have been socially implemented. Therefore, the effectiveness and impact of the project are high. Although the project period was as planned, the project cost slightly exceeded the plan. Therefore, the efficiency of the project is fair. The sustainability of the project has been achieved at research institutions. However, as mentioned above, the institutional and organizational aspect remained undeveloped in the Sabah government. Considering these results, the sustainability of the project effects is fair.

In light of the above, this project is evaluated to be satisfactory.

4.2 Recommendations

4.2.1 Recommendations to the Implementing Agency

(1) UPM and UMS are recommended to pitch the research results of this project (including those from research projects developed after this project) again to the Sabah palm oil industry. Compared to the time of project completion, there may be a greater awareness of sustainable development, including RSPO/MSPO certification, among palm oil mills in Sabah. For example, the government-affiliated palm oil mill located in the eastern part of Sabah (which was a candidate for collaboration at the time of the project planning, but this idea did not materialize owing to the deteriorating security situation in the eastern part of the state) may be a good candidate for the initial site for the application of the research results because its profitability requirements may be lower than those of privately-owned mills, especially small- and medium-scale ones. When making such a pitch, it is recommended that the universities and private companies, if they can, update the business models by incorporating the project's research results, including the research results from the research developed after this project, to make them more attractive to the palm oil industry in the state.

(2) The NRO, Sabah, is recommended to identify relevant government agencies that should be involved to ensure that the project's research results and the outcomes of the activities the universities and companies may make based on the recommendation above will contribute to the conservation of biodiversity in Sabah and promote the discussion involving these agencies.

4.2.2 Recommendations to JICA

JICA is recommended to monitor the implementation of the above recommendations for the use by the NRO, Sabah, of the research results in the state.

4.3 Lessons Learned

(1) Significance of setting an overall goal in the SATREPS project proposal

The overall goal and its indicators are sometimes not set in the project design matrix (PDM) for SATREPS projects, but this project has set the overall goal and its indicators in the PDM and reviewed their relevance multiple times during the project implementation to replace them with appropriate ones. As a result, the project explicitly incorporated indicators representing the application by the palm oil industry of the technologies and business models developed and used a project design that always made stakeholders aware of the outcomes of the joint research, enabling the SATREPS project to commercialize the project's outputs to help their social implementation (the development and dissemination of business models) during the project implementation period. These achievements were positively received by the JST. On the other hand, because the commercialization and social implementation of research results generally take a long time, it is difficult to set the overall goal that is achievable within three years of the project completion pursuant to the PDM principle. In such a case, a project can potentially use an approach in which the aim of the overall goal and its indicators is to provide direction without assuming that they need to be achieved within three years. In so doing, however, it would be necessary to make it even more explicit at the time of the ex-ante evaluation that such aim of the overall goal differs from that in a typical PDM.

(2) Manifestation of the effects of SATREPS based on the relationships established through years of research cooperation and prior JICA projects

The project was based on long-term research conducted by the Kyushu Institute of Technology and UPM, and the project's core members consisted of researchers from these institutions. In addition, the key members of the counterparts in a series of JICA

Technical Cooperation projects (BBEC Phase 1, BBEC Phase 2, and SDBEC) also became its core members. Thus, by the time the project started, conditions that are necessary for the early stages of joint research had already been established to a considerable extent, including the strengthening of the relationship and trust-building and the capacity development among the researchers in the partner country.[25] It is likely that this factor has allowed the SATREPS project to achieve not only significant research results but also efforts on social implementation. It has been reported that many of the projects adopted as SATREPS projects are based on a project structure that takes advantage of long-term relationships of trust between Japanese researchers and the researchers in the counterpart country.[26] This project is one such project.

(3) Creating a system for the social implementation of the outputs of the SATREPS project

In this project, when the PDM was revised, the item "Consideration within the Sabah government on the use of research results," which used to be a project-purpose indicator, was changed to an overall-goal indicator. As a result, the division of roles between different state government agencies was not established within the project period, and the anticipated examination within the government failed to take place. This is likely to be one of the reasons for the lack of social implementation of the research results within Sabah. In planning a SATREPS project that requires an examination within the government concerning its social implementation, it would be necessary to identify the necessary government agencies for the measures for social implementation and formulate a project implementation structure and project activities (for the government to start the examination within the project period) necessary to get those agencies involved. Before completing the project, it would be further necessary to readjust the measures within the government required after the project completion and have them agreed upon among the relevant parties, including such government agencies. After the project completion, JICA should continue monitoring whether these agencies are conducting the necessary examination.

[25] Sato, J. et al. (2000). *Fiscal Year 2019 Ministry of Foreign Affairs ODA Evaluation: Evaluation of the SATREPS Program (Science and Technology Research Partnership for Sustainable Development)* (Ministry of Foreign Affairs), organizes the manifestation effects of SATREPS projects by dividing the stages from the intensification of joint research to the social implementation into three phases: "Personnel Exchange/Strengthening of Relationship with Counterpart Research Institution," "Capacity Development of Researcher and Research Institution of Counterpart Country and Dissemination," and "Effort for practical benefit of research outcomes" (p. 33).
[26] Ibid, p. 32.

Attachment: Status of the achievement of output indicators as of project completion

Outputs	Indicator	Results for the indicator
Output 1 The effectiveness of zero-discharge is ensured through energy efficiency improvement resulting in surplus biomass and excess energy at showcase facilities of zero-discharge established at an oil mill.	1. The showcase facilities aiming for zero-discharge are established at an oil mill.	Achieved
	2. The operation records are maintained properly for the showcase facilities.	Achieved
	3. The excess energy, biomass, hot steam and methane gas are available for effective utilisation.	Achieved
	4. Bio-composite, charcoal and compost are produced from the excess biomass.	Achieved
	5. Discharged water from the showcase facilities is fully recycled.	Achieved
Output 2 Viability of business model is verified through the proposed zero-discharge and creation of new industry from surplus biomass and excess energy.	1. Viable business model and model investment plans are proposed based on the cost-benefit analysis.	Achieved
	2. New products made by the materials from surplus biomass will be produced on a trial basis.	Achieved
Output 3 The innovative research is pursued on the effective utilization of palm biomass and energy for the reduction of the environmental burden caused by palm oil processing.	1. A baseline survey report is produced.	Achieved
	2. Sampling sites are decided to investigate the effect of our zero-discharge (recycled water) on the biodiversity.	Achieved
	3. The effect of zero-discharge (recycled water) on the bio-diversity recovery is evaluated scientifically.	Continuing*
	4. The effect of superheated steam is confirmed for the production of nano fibers to be used in nano bio-composites.	Achieved
	5. The control of the nano-interface between palm biomass fibers and mother plastics by gas-phase polymerization is confirmed.	Achieved
	6. A master batch of nano bio-composites is provided.	Achieved
	7. A nano bio-composite with nano-space (5).	Achieved
	8. Supply of a bio-composite equal to or greater than the qualities of the mother plastics can be confirmed with price reduced by 20%.	Achieved
	9. A production method for nano-cellulose fibers is proposed.	Achieved
	10. The saccharification efficiency from palm biomass of more than 80% is confirmed.	Achieved
	11. Bio-charcoal with Calorific Value of 20MJ/kg and compost at NPK of 5% are produced from palm biomass.	Achieved
Output 4 Validity of the business model and the research results are shared extensively and recognized within the Sabah government and domestic/international investors and firms.	1. Workshops, seminars and trade fairs are organised regarding the business model and research results at least twice a year.	Achieved
	2. At least 100 organisations/agencies in total participate in such events.	Achieved
	3. The events are exposed to mass media.	Achieved

Source: JICA Terminal Evaluation Report, JST Final Report

* Indicator 3 for Output 3 is considered to have been achieved to the extent achievable within the project period given the description of the indicator ("The effect of zero-discharge (recycled water) on the bio-diversity recovery is evaluated scientifically.").