Internal Ex-Post Evaluation for Technical Cooperation Project (SATREPS[1])

Conducted by Mozambique Office: March, 2023

Country Name	**Sustainable Jatropha Biofuel Production in Mozambique**
Republic of Mozambique	

I. Project Outline

Background	Mozambique depended on oil imports which accounted for 11% of total imports and induced a fiscal burden. At the same time, since 80 % of primary energy consumption depended on firewood, deforestation associated with firewood collection became a serious problem. Therefore, the government of Mozambique aimed at introduction of renewable energy including biofuel derived from Jatropha for reduction of oil imports and forest conservation. On the other hand, while the country has adequate land for Jatropha cultivation of approximately 3.3 million ha, scientific knowledge on Jatropha cultivation had not been accumulated in the country. In addition, there was almost no research on safety of biodiesel fuel (BDF) and solid fuel using Jatropha and wastewater treatment after BDF refining. Under such situation, research on sustainable utilization of Jatropha was required.		
Project Objectives	Through development of cultivation technology and breeding of Jatropha, BDF production and effective utilization of residues, safety evaluation of BDF and byproducts, as well as proper management methods of hazard and exposure BDF and solid fuel, the project aimed at establishment of Jatropha cultivation system suitable for semi-arid areas in Mozambique and scientific verification of effectiveness of environmental conservation, thereby contributing to improvement of yield of Jatropha, enhancement research capacity for BDF and dissemination of power generation from Jatropha. 1. Expected Overall Goal: 1) Cultivation and breeding technologies are succeeded by researchers in Mozambique and the yield of Jatropha seeds in unit area is improved. 2) Research capacities of researchers and students in Eduardo Modlane University (Universidade Eduardo Modlane; UEM) are enhanced, and UEM and PETROMOC lead the research and development BDF in Mozambique. 3) Power generation from Jatropha oil is continued in the model village and the model is propagated to other regions 2. Project Purpose: Jatropha cultivation system suitable for semi-arid areas in Mozambique is established. Effectiveness of environmental conservation and improvement are scientifically verified by the establishment of mentioned cultivation, conversion and utilization technologies.		
Project Activities	1. Project Site: Mapto and Boane (Mapto Province), Licaca Village (Inhambane Province) 2. Main Activities: 1) 1) Cultivation test of non-toxic Jatropha, component analysis of seeds and fruits and application test of oil cake derived compost as alternative fertilizer, 2) Development of technologies to produce solid fuels, combustion experiments of BDF and solid fuel, 3) Safety evaluation of Jatropha BDF and solid fuel products as well as soil after using fertilizer made from Jatropha press cake, 4) Energy and Greenhouse Gas (GHG) balance evaluation based on Lifecycle Assessment (LCA) methodology and evaluation of environmental effects caused by land use change, 5) Cost benefit analysis of BDF and solid fuel production and delivery system and examination on village electrification based on Jatropha cultivation, and so on. 3. Inputs (to carry out above activities) Japanese Side 1) Experts: 23 persons 2) Trainees received: 8 persons 3) Equipment: BDF plant, diesel power generator, Lab and field equipment, vehicles, computers, printer, photocopier, office furniture, electric appliances, etc. 4) Local operation cost: Administrative expenses, travel expenses and so on. Mozambican Side 1) Staff allocated: 19 persons 2) Facilities and land: Office space and laboratory in UEM, office space and experimental field in Boane, BDF plant in Petróleo de Moçambique S.A. (PETROMOC) 3) Local operation cost: Utility cost borne by UEM and PETROMOC, payroll for technician born by UEM		
Project Period	Ex-ante: April 2011- March 2016 Actual: February 2012 – February 2017	Project Cost	Ex-ante: 306 million yen Actual: 362 million yen
Implementing Agencies	Eduardo Modlane University (UEM), Petróleo de Moçambique S.A. (PETROMOC)		
Cooperation Agency in Japan	The Tokyo University, Kanazawa Institute of Technology, Kurume University, Nippon Biodiesel Fuel Co., Ltd., Association of African Economy and Development Japan ECA Committee (AFRECO)		

II. Result of the Evaluation

< Special Perspectives Considered in the Ex-Post Evaluation >

Based on the research outputs of this SATREPS project, the "Power Kiosk Project Using Jatropha Biofuel by No Electricity Village People (JICA Partnership Program/Support type April 2017- September 2019)" was implemented as a follow-up project. Since the follow-up technical cooperation project aimed at promotion of electrification by using Jatropha Biofuel based on the research outputs by the SATREPS project, this ex-post evaluation examined contribution of the technical cooperation project to the expected Overall Goal and the utilization of the research outcomes by the SATREPS project (社会実装) .

[1] SATREPS: Science and Technology Research Partnership for Sustainable Development

1 Relevance

<Consistency with the Development Policy of Mozambique's at the Time of Ex-Ante Evaluation >

The Project was consistent with Mozambique's policies of the "National Policy and Strategy for Biofuel" (2009) setting a legal framework to introduce biofuel to substitute fossil fuel and the "Strategy for New and Renewable Energy Development" (2011-2025) aiming at promotion of more efficient energy system.

<Consistency with the Development Needs of Mozambique's at the Time of Ex-Ante Evaluation>

The Project was consistent with Mozambique's development needs for introduction of renewable energy including biofuels such as BDF derived from Jatropha in order to reduce import oil for improvement of trade balance and to promote forest conservation by reduction of firewood consumption.

<Consistency with Japan's ODA Policy at the Time of Ex-Ante Evaluation>

The Project was consistent with Japan's ODA Policy for Mozambique prioritizing support for climate change and environment area as one of the three priority areas by the policy dialogue between Mozambique and Japan in March 2011[2].

<Evaluation Result>

In light of the above, the relevance of the project is high.

2 Effectiveness/Impact

<Status of Achievement of the Project Purpose at the time of Project Completion>

The Project Purpose was partially achieved at the time of project completion. A production process for BDF derived from Jatropha was established and the model BDF plant at PETROMOC, a Mozambican national fuel company, was operated by the Mozambican counterparts (Indicator 1). LCA on electrification of off grid village by the Jatropha fuel was conducted and GHG emission reduction was quantitatively estimated (Indicator 3). Although impacts of Jatropha cultivation were assessed, Jatropha cultivation technology in degraded land was not fully established since the SATREPS project used lands which had already prepared for Jatropha cultivation (Indicator 2).

<Continuation Status of Project Effects at the time of Ex-post Evaluation>

The project effects have partially continued since project completion. Some of the research outputs by the SATREPS project have been utilized and the research activities related to the SATREPS project have been continued at the time of ex-post evaluation. In June 2016, UEM signed an agreement with the Fund of Energy (Fundo de Energia: FUNAE) in order to implement a project "Increase Access to Energy Services through Installation of Multifunctional Platform (PMF) powered by Coconut Oil as Biofuel" to provide grain milling services, refrigeration, battery charging, lanterns, an energy store for sales of small renewable energy products for income generation, in Marrucua, Morrumbene District, Inhambane Province in 2018. In addition, the research outputs by the SATREPS project, including Jatropha cultivation method, Jatropha BDF production system and Power Kiosk using Jatropha biofuel, have been utilized for the research activities by the graduated students for their degrees and for undergraduate students. The courses of the Chemical Engineering Department of the Faculty of Engineering of UEM, such as the "Chemical Engineering Laboratories II" and the optional discipline of "Energy" have been developed by using the research equipment installed by the SATREPS project.

Some research equipment installed in the Faculties of Engineering, Science and Agronomy and Forest Engineering (FAEF) by the SATREPS project including Jatropha BDF plant have been utilized for the research works by the undergraduate and graduate students. Also, FAEF transferred the agricultural equipment installed in the Boane experimental field to Sabie and has used for agronomic testing. On the other hand, the Power Kiosk has not been used continuously because the Agricultural Association of Licaca has not yet managed to produce specific plan for its use.

<Status of Achievement for Overall Goal at the time of Ex-post Evaluation>

The Overall Goals have been not achieved. The Overall Goal 1 has not been achieved since no new variety was introduced and no field of the bred trees was established due to the lack of finance for the activities (Indicator 1-1). The Overall Goal 2 has been partially achieved. While the six research papers related to the research outputs by the SATREPS project were published and the three papers have been under review (Indicator 2-1), the number of graduate and undergraduate students who completed their degree theses related to the research outputs by the SATREPS project was far below the target (Indicator 2-2). The Overall Goal 3 has not been achieved. According to UEM, a national development program must be run by the government. It is deemed that there are no known initiatives to update the National JBDF Development Program (Indicator 3-1). In terms of rural electrification by using the research output of the SATREPS project, there was no electrified village by the Jatropha biofuel nor Power Kiosk using Jatropha biofuel because of the lack of fund to disseminate the model developed by the SATREPS project (Indicator 3-2).

<Other Impacts at the time of Ex-Post Evaluation>

There are some positive impacts of the Project confirmed at the time of the ex-post evaluation. While the Power Kiosk installed by the SATREPS project has not been regularly operated without the specific plan, the Power Kiosk has been installed by a private construction company at the Agricultural Association of Licaca, a non-profit organization formed to provide services to members, mostly women. Upon installation of the Power Kiosk, the association began to provide services such as battery rental, battery charging, phone charging, batteries and other services for members of the association and for the Licaca community. The Power Kiosk has been run by a woman. As of 2018, the Agricultural Association of Licaca benefited from the support of the "Power Kiosk" Project using biofuel through Jatropha for people in the Village without Access to Electricity" under the JICA Partnership Program. The project resulted in the creation and legalization of the company, " Quiosque de Energia de Licaca "

As mentioned above, the capacity of researchers involved in the activities of the SATREPS project has been improved through the continuation of the related research activities and the academic achievements of the graduate and undergraduate students based on the research outputs by the SATREPS project. The researchers used the research outputs of the SATREPS project to prepare the project proposal "Biomass for Energy", funded by the government of Sweden for the period 2017-2022. Furthermore, the research outputs of the SATREPS project are used in the teaching and learning processes in undergraduate courses and especially in the classes of the two master courses of "Master in Renewable Energy Science and Technology" and "Master in Renewable Energy Systems Management". With a duration of 2 years, the two master's courses began in 2019 and are coordinated by the Eduardo Mondlane University Energy Research Center.

[2] Ministry of Foreign Affairs, Japan, "ODA Databook" (2011)

No negative impact by the SATREPS project was confirmed at the time of ex-post evaluation.

<Evaluation Result>

Therefore, both the effectiveness and impact of the project is fair.

Achievement of Project Purpose

<table>
<tr><th>Aim</th><th>Indicators</th><th>Results</th><th>Source</th></tr>
<tr><td rowspan="3">(Project Purpose)
Jatropha cultivation system suitable for semi-arid areas in Mozambique is established.
Effectiveness of environmental conservation and improvement are scientifically verified by the establishment of mentioned cultivation, conversion and utilization technologies.</td><td>Indicator 1:
Biofuel production model with improved GHG and energy balance is transferred to partner research institutes, and is run by C/P researchers.</td><td>Achievement Status: Achieved (Continued)
(Project Completion)
● Jatropha BDF production process was established.
● BDF plants were operated at PETROMOC by the Mozambican counterpart members.
(Ex-Post Evaluation)
● The BDF plant at FAEF has been utilized for the research works by the undergraduate and graduate students of UEM.</td><td>● Terminal Evaluation Report,
● JST Terminal Report,
● Questionnaires survey with UEM</td></tr>
<tr><td>Indicator 2:
Impact of Jatropha cultivation and biofuel production technologies making use of currently degraded land is verified.</td><td>Achievement Status: Not verified. (Partially continued)
(Project Completion)
● Since the SATREPS project used land already prepared for the cultivation of Jatropha, the achievement level of the indicator was not verified.
● Jatropha cultivation technology in degraded land was not fully established but impacts of Jatropha cultivation was assessed.
(Ex-Post Evaluation)
● The Jatropha cultivation method and the Jatropha BDF production system have been utilized by the undergraduate and graduate students for their degree works in FAEF.</td><td>● Terminal Evaluation Report,
● JST Terminal Report,
● Questionnaires survey with UEM</td></tr>
<tr><td>Indicator 3:
Greenhouse gas emission reduction of a designated Jatropha production and utilization system is quantitatively estimated and improvement of the system performance will be proposed.</td><td>Achievement Status: Achieved (Partially continued)
(Project Completion)
● LCA analysis of electrification of off grid village by Jatropha fuel was conducted and GHG emission reduction was quantitatively estimated.
<table>
<tr><th>Fuel for power generation</th><th>Fossil energy resource inputs</th><th>GHG emission</th></tr>
<tr><td>100% diesel</td><td>15.722MJ</td><td>0.289kg CO2 equivalent</td></tr>
<tr><td>60% Jatropha crude oil mixed diesel (improved variety by the SATREPS project)</td><td>6.629MJ</td><td>0.142kg CO2 equivalent</td></tr>
<tr><td>60% Jatropha crude oil mixed diesel (native variety in Mozambique)</td><td>7.470MJ</td><td>0.188kg CO2 equivalent</td></tr>
</table>
(Ex-Post Evaluation)
● The Power Kiosk installed at FAEF has been used by a professor of the Department of Physics for his doctoral thesis.
● The pilot installation of Licaca Power Kiosk did not operate regularly in the period of 5 years after the completion of the SATREPS project.</td><td>● Terminal Evaluation Report,
● JST Terminal Report,
● Questionnaires survey with UEM</td></tr>
<tr><td>(Overall Goal 1)
Cultivation and breeding technologies are succeeded by researchers in Mozambique and the yield of Jatropha seeds in unit area is improved.</td><td>Indicator 1-1:
A new variety with yield of over two times compared with local varieties is bred in the project site, and field of the bred trees is established by UEM for seed production.</td><td>Achievement Status: Not achieved
(Ex-post evaluation)
● No new variety was introduced and no field of the bred trees was established.
● It was not possible to carry out this activity because the plan presented by FAEF was not financed.</td><td>Questionnaires survey with UEM</td></tr>
<tr><td>(Overall Goal 2)
Research capacities of researchers and students in UEM are enhanced, and UEM and PETROMOC lead the research and development BDF in Mozambique.</td><td>Indicator 2-1:
Research papers on following areas are published:
1) BDF production and effective use of residues.
2) Safety evaluation of BDF and byproducts at the production and utilization processes.</td><td>Achievement Status: Achieved.
(Ex-post evaluation)
● The following 6 papers were published after the project completion:
➢ Effect of Storage Conditions on the Quality of Jatropha Curcas Oils
➢ Technical and Economic Assessment of Hybrid Off-Grid Energy System in Rural Licaca, Mozambique.
➢ Production of Biodiesel from Jatropha Curcas L., and Engine Performance with Blends Fuels
➢ Generator Engine Performance and Exhaust Gas Emissions, Using Biodiesel from Jatropha Curcas with Kerosene Blends
➢ An optimized solid-liquid method for rapid extraction of phorbol</td><td>Questionnaires survey with UEM</td></tr>
</table>

	3) Environmental evaluation for biofuel production and utilization.	esters from Mozambican Jatropha seeds ➢ Efficient vortex-assisted extraction of phorbol esters from Jatropha leaves and correlation between leaves and seeds in phorbol esters content ● 3 papers have been under review: ➢ Determination of genetic gain in seed yield of new genotypes of Jatropha (Jatropha curcas L.) through the evaluation of seedlings. ➢ Vortex-assisted solid-liquid extraction for rapid screening of oil content in Jatropha seed: an alternative to the modified Soxhlet method. ➢ Effect of heterosis and correlation analysis on seed traits using reciprocal crosses in Jatropha curcas L. grown in Mozambique. Industrial Crops and Products	
	Indicator 2-2 2 researchers obtain a Doctor degree, and in total over 100 graduate and undergraduate students complete their thesis related to the project.	Achievement Status: Not achieved. (Ex-post evaluation) ● Academic achievements based on the research outputs by the SATREPS project were as follows: ➢ 1 researcher obtained a Doctorate degree in 2020. ➢ 2 graduate students completed their master's degree theses during the period from 2016 to 2019 ➢ 18 undergraduate students completed their research papers during the period from 2016 to 2019.	Questionnaires survey with UEM
(Overall Goal 3) Power generation from Jatropha oil is continued in the model village and the model is propagated to other regions	Indicator 3-1: Key and basic data are to be compiled necessary for formation of the National JBDF Development program.	Achievement Status: Not achieved. (Ex-post evaluation) ● UEM understand that a national development program must be run by the government. It is deemed that there are no known initiatives to update the National JBDF Development Program.	Questionnaires survey with UEM
	Indicator 3-2: 5-10 villages are expected to be energized by Jatropha	Achievement Status: Not achieved. (Ex-post evaluation) ● No village was electrified by using Jatropha biofuel nor the Power Kiosk using Jatropha biofuel.	Questionnaires survey with UEM

3 Efficiency

Although the project cost exceeded the plan (the ratio against the plan: 118%), the project period was as planned. Since the market environment for Jatropha BDF changed in Mozambique, the project scope was changed to introduce activities for rural electrification activities by using Jatropha biofuel which required additional costs to purchase electrification equipment such as generators. (the ratio against the plan: 100%). The project outputs were produced as planned.

Therefore, the efficiency of the project is fair.

4 Sustainability

<Policy Aspects>

The research activities related to the SATREPS project have been backed up by the government policy. The "Government Five-Year Plan 2020-2024" (PQG 2015-2019) focuses a) development of human and social capital by establishing programs and synergies with higher education, professional technical, research and technological base institutions that contribute to stimulate innovation and entrepreneurship, b) promoting employment and improving productivity and competitiveness by promoting the value chain of national primary products ensuring the integration of local content, and c) development of economic and social infrastructures by increasing the access and availability of electricity, liquid fuels and natural gas for the development of socio-economic activities.

<Institutional/Organizational Aspects>

There are no changes in the organizational/institutional mechanism to use the research outputs of the SATREPS project. The utilization of the research outcomes is being made through the network established between UEM, government entities and researchers from Mozambique and the Kingdom of Sweden. This network was created in 2017 and envisaged the development of a Ph.D. program in renewable energies to be carried out in a sandwich regime with the Swedish Universities of Chalmers and Malardalen, within the scope of the collaboration between UEM and the Swedish International Development Agency (Sida). The doctoral program is coordinated by CPE based at the Faculty of Sciences, which is located on the Main University Campus of UEM, as mentioned above. The research outputs of the SATREPS project are used by teachers and researchers involved in teaching the master's degree in Science and Technology of Renewable Energies, also coordinated by CPE.

The maintenance of the equipment installed in the Power Kiosk, in Licaca, District of Jangamo could only be guaranteed with the existence of funds for the continuous realization of the project activities. A UEM engineer stopped working at the beginning of 2020, he was responsible for the laboratory installed at PETROMOC, he retired due to financial difficulties that the University Foundation has faced in recent years but the laboratory has been continuously utilized for the research activities by the UEM researchers and students. A technician left UEM in 2017, was responsible for the Boane experimental field and directly assisted the activities of the agricultural area in Licaca. However, the equipment installed in the Boane experimental field were transferred to Sabie and they have been still in use.

<Technical Aspects>

At the end of the project, it was found that the researchers improved their research capacity to continue with the research activities related to the thermal and biochemical conversion of biomass into energy. The number of researchers has increased due to the return of 3 employees who obtained a doctoral degree in Sweden. On the other hand, although two senior officials left the research activities and UEM

due to lack of budget to pay their salaries, the UEM researchers and students have been able to continue the related research activities using the research equipment and facilities installed by the SATREPS project.

The support and improvement of research activities have been achieved by the continuous participation of all researchers in activities to supervise research projects of disciplines in the energy area taught at the Faculty of Engineering (in the Department of Chemical Engineering), Faculty of Sciences and Faculty of Agronomy and Forest Engineering and in the supervision / co-supervision of the work of master and Ph.D. students in Science and Technology of Renewable Energies, all offered by CPE. Furthermore, the participation in research works developed in partnership with national and foreign higher education and research institutions have contributed to sustaining and improving their research capacities

The improvement of scientific literacy by government authorities is evident in the successive five-year plans (PQG 2015-2019 and PQG 2020-2024) that provide for the production of energy from solutions similar to those studied ones under the SATREPS project.

<Financial Aspects>

UEM has continued to finance research activities with its own and external resources. For example, the project "Biomass for Energy" is funded by Sida under the financing of the general program called "Building a Research and Education Environment for Modern Renewable Energy Systems" (BREEMRES) and coordinated by CPE. In addition, as mentioned above, the "Increase Access to Energy Services through Installation of Multifunctional Platform Powered by Coconut Oil as Biofuel" project in Marrucua, Morrumbene District, in the province of Inhambane, has been implemented under the partnership agreement signed in 2016 between UEM and the Energy Fund (FUNAE).

The financial resources of the BREEMRES program will be used to finance part of maintenance services for some of the research equipment installed by the SATREPS project that will be used for research works done by master's and doctoral students in Renewable Energy Science and Technology.

<Evaluation Result>

In the light above, there has been no concern from any aspects. Therefore, the sustainability of the effects through the Project is high.

5 Summary of the Evaluation

The project partially achieved the Project Purpose for establishing the sustainable Jatropha cultivation system and the project effects have been partially continued. While the Overall Goal 1 for the introduction of new variety of Jatropha and the Overall Goal 3 for village electrification by the Jatropha oil have not been achieved yet, the Overall Goal 2 for enhancement of research capacity has been progressed. As for efficiency, the project cost exceeded the plan.

Considering all of the above points, this project is evaluated to be satisfactory.

III. Recommendations & Lessons Learnt

Recommendations for Implementing Agency:

（For UEM）

- It is essential for UEM to maintain links with FUNAE to promote renewable energies from biomass, including Jatropha; and to disseminate the research outputs by the SATREPS project so that other actors can be benefited through use of the scientific information obtained the research works related to the SATREPS project.

Lessons Learnt for JICA:

- It is necessary for JICA to maintain close contact with the different stakeholders in order to maximize the project effects of the SATREPS project because realization of the expected research outcomes requires certain period of time and follow up by other stakeholders, including development partners as funding agencies. Also, it is essential to consider sustainability of expected research activities and dissemination of the research outputs for utilization of the research outcomes from the project preparation stage to the post project period.

No Photo available at the time of ex-post evaluation