

GREENING MINED AREAS IN THE PHILIPPINES (GMAP) PROGRAM

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DEPARTMENT OF SCIENCE AND TECHNOLOGY-
NATIONAL RESEARCH COUNCIL OF THE PHILIPPINES
UNIVERSITY OF THE PHILIPPINES LOS BAÑOS

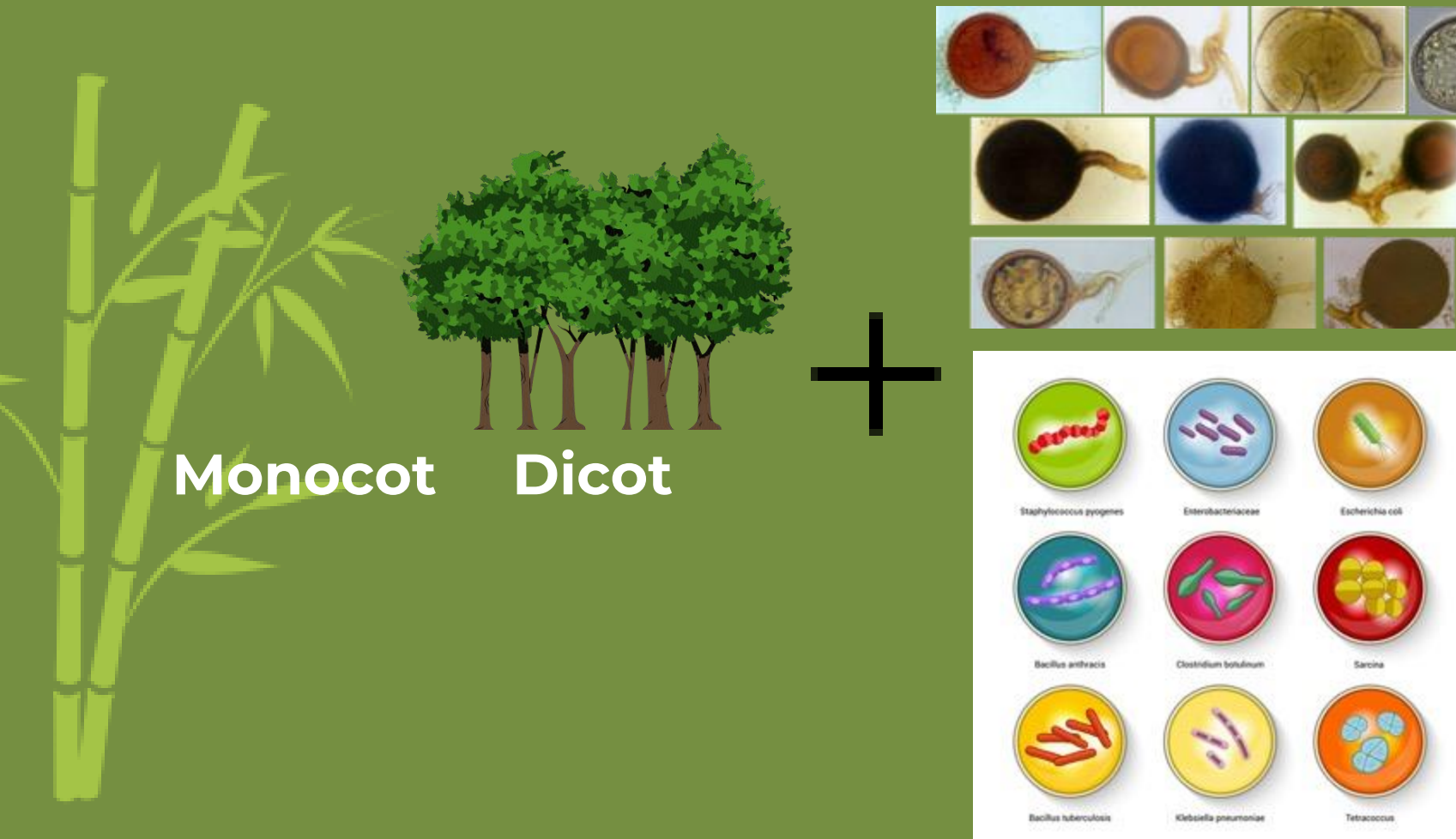
GMAP PROGRAM RESEARCH TEAM

- women-led research team from UP Los Baños initiated the bioremediation of mined areas in the Philippines

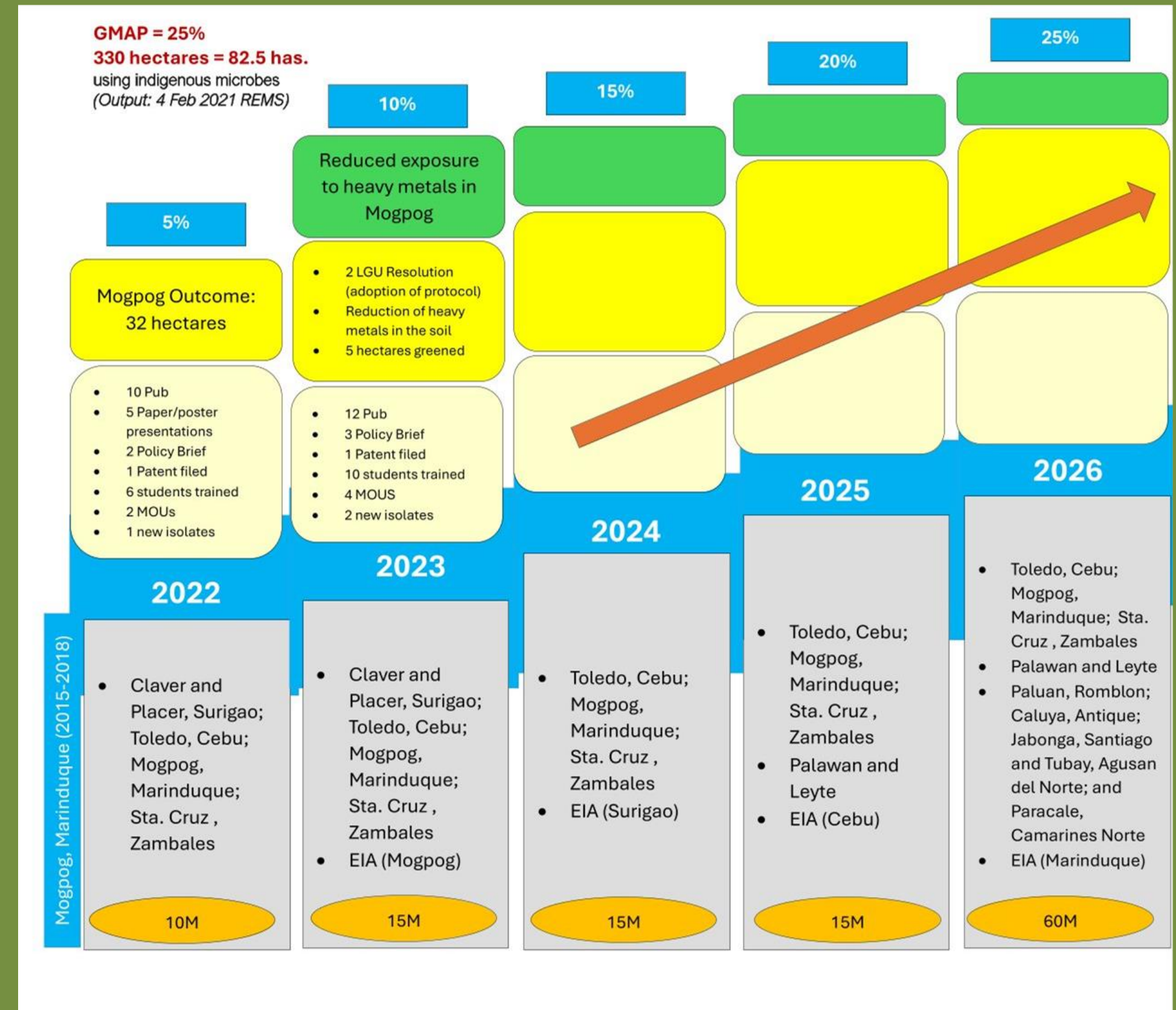


OUR VISION

To bring back 82.5 ha (25%) barren lands through GMAP into its productivity using the Marinduque Bioremediation Protocol (MBP) and the monocot-dicot-microbes' symbioses, with high priority in the use of native forest trees and bamboos in restoring mine areas.



TECHNOLOGY ROADMAP



Significance of the GMAP Program

Address successful **Rehabilitation** efforts

Inform, Train and **Involve** the community

Acquire knowledge on the heavy metals clean up and plant absorption

Select plants that are appropriate for rehabilitation

Include bamboo in bioremediation

Discover new beneficial (mycorrhizal fungi and nitrogen fixing bacteria) microbes in the field sites for their potential as biofertilizers

PROGRAM OBJECTIVES

BIOREMEDIATION

Encourage community to engage and actively participate in knowledge information education dissemination

Establish nursery and field trials to assess the effectiveness of the Marinduque Bioremediation Protocol (MBP) in greening mined areas

Assess the potential of Marinduque isolates from Cu mined area (UPLB-NRCP-NewNFB and UPLB-NRCP-NewMYC, currently renamed as MogNFB and MogMYC, respectively) for the rehabilitation of mined lands irrespective of heavy metals present

Search for new beneficial mycorrhizal fungi and nitrogen fixing bacteria indigenous in different mined areas

Monitor changes in plant growth, survival, nutrient status, rhizosphere microbial population and soil nutrients and heavy metals concentration due to microbial inoculation under nursery and field conditions



Collaborative Partnerships

During field planting and growth monitoring, men and women from mining companies, collaborators (universities, local government agencies, etc.) and the GMAP team are united in greening mined areas in a sustainable manner. Through this, they are **trained**, **involved**, and **contributed** to sustainable solutions, fostering gender equality in environmental initiatives.



MILESTONE

The GMAP research team had developed a microbial-based protocol that can effectively rehabilitate unproductive mine tailing areas in the Philippines by converting barren lands into mini forests. Thus, enhancing carbon capture and reducing heavy metals contamination to surrounding communities.

First GMAP project (Phase 1) was done in 2015-2018 in a copper gold mined and mine tailing dumpsite in Mogpog, Marinduque where the Marinduque Bioremediation Protocol (MBP) was developed.

The protocol developed in Marinduque had been adopted by the local government units and replicated in nickel and copper/ gold mined areas in Claver and Placer, Surigao del Norte from 2020 - 2023 (Phase 2)

From April 2023 – March 2026 (Phase 3), the MBP is being implemented in the mined areas in Sta Cruz, Zambales (Phase 3A), Mogpog, Marinduque (Phase 3B) and Toledo, Cebu (Phase 3C)

MOVING FORWARD: Proposals for Phase 4 (Palawan and Leyte/Smar) and Phase 5 (Antique, Agusan del Sur, and Camarines Sur) have been approved funding agency by DOST-NRCP



GMAP SUCCESS STORIES

Through the Marinduque Bioremediation Protocol and using the microbial technology (MYKORICH®, MYKOVAM®, MYKOCAP®, MYCOGROE and new inoculants derived from copper, nickel and gold mined lands)...

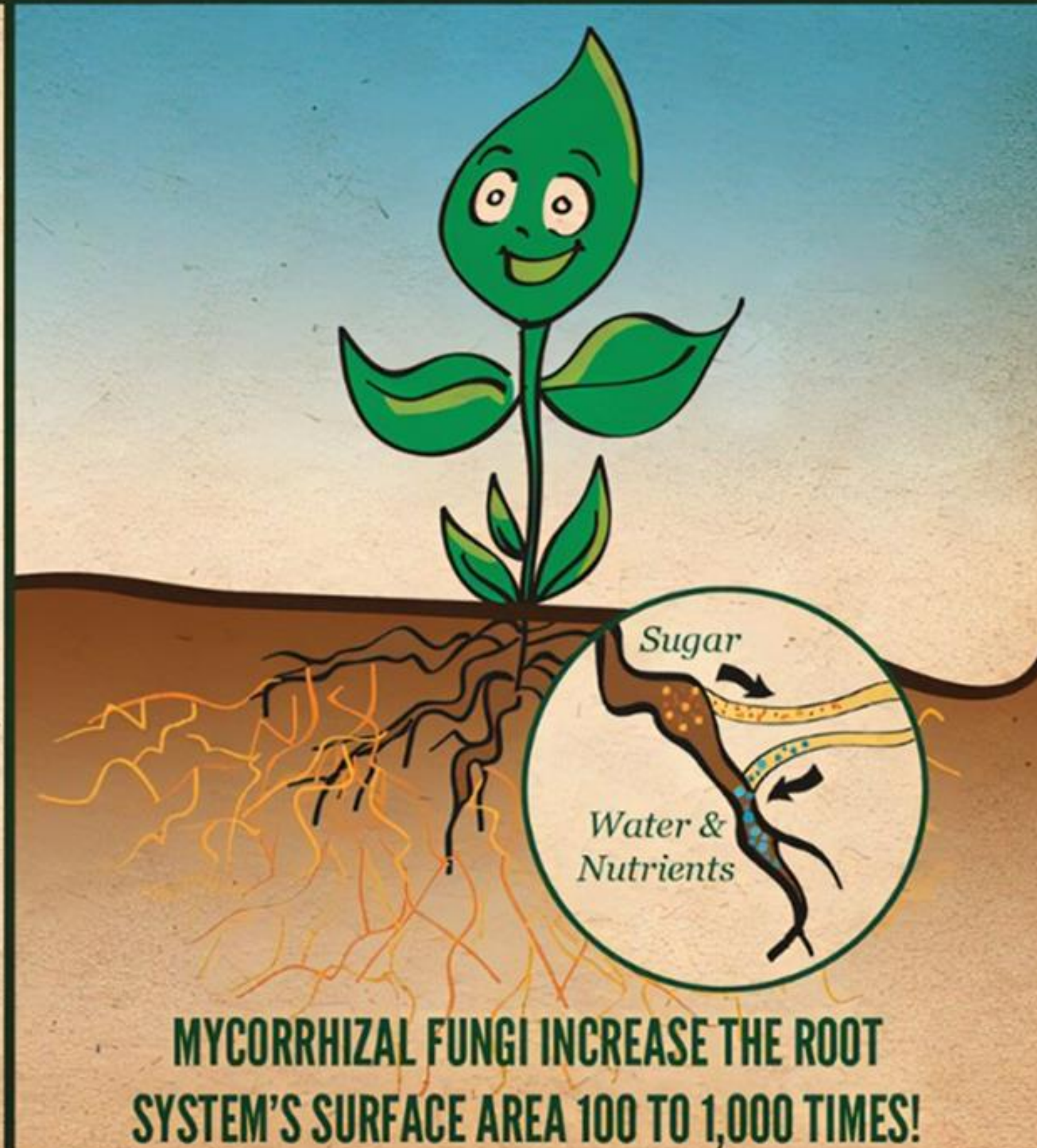
The local community regained their hope for a better environment for the present and next generations to come.



WHY DO YOUR PLANTS NEED MYCORRHIZAE FUNGI?

Mycorrhizae Fungi are beneficial, and form a symbiotic relationship with plant roots.

The fungi receives sugar from the root. In exchange, it absorbs and sends soil nutrients and water back to the plant. When those nutrients and water are depleted, the fungi simply reaches further into the soil for more.





Bioremediation Protocol Developed

05. Blanket application of recommended rate of soil amendments (lime, vermicompost and initial soil ameliorants).

04. Establishment of field trial sites and field planting at 6th month and onward.

03. Soil pre-analysis and liming recommendation.

02. Seedling inoculation with the UPLB-developed biofertilizers and newly developed inoculants containing native beneficial, plant growth promoting soil microorganisms at nursery stage.

01. Establishment of nursery experiments for leguminous and non-leguminous native plants and bamboos.

08. Monitor plant growth, survival, nutrient status and changes in soil nutrients and heavy metals concentration under nursery and field conditions.

09. Conduct of education campaign and fora to disseminate research results among the concerned stakeholders.

07. Search for new beneficial mycorrhizal fungi and nitrogen fixing bacteria associated with the stress-tolerant plants in the locality.

06. Application of 10 g NPK one month after field planting or during field planting as long as seedling survival is high (greater than 90%). Reapplication of 10 g NPK fertilizer after one year if needed (to correct nutrient deficiency).



Phase 1 (Dec 2015 to Dec 2018) FROM BARREN (>35 YRS) TO YOUNG MINI FOREST

Rehabilitation of mined area using mycorrhizal fungi and nitrogen fixing bacteria, plus soil amendments

Capayang, Mogpog, Marinduque mined area from
2006 until 2013 via Google Earth

2.5ha

Google Earth

Imagery Date: 11/24/2006 13°30'11.52" N 121°51'46.31" E elev 10 m eye alt 1.68 km

Capayang mined area in Nov 2018 with INTERVENTION
by the NRCP-DOST Project
Dec 16, 2015 – Dec 15, 2018
27 MONTHS AFTER PLANTING

Photo by: Mar Maningas, Nov 2018

Seedling survival due to inoculation and soil amendments



TREATED:
95% SURVIVAL

UNTREATED:
26% SURVIVAL

After 22 months

There was a **95%** if treated with microbial biofertilizers + other soil amendment as compared with **26%** in the control (no amendments)

After 27 months

Survival is **92%** if with microbial biofertilizers + other soil amendment as compared with only **15%** in the control (no amendments)

After 36 months

Survival is **90%** if with microbial biofertilizers + other soil amendment as compared with **zero** survival in the control (no amendments)

Marinduque mined-out area before and after 18 mo with microbial-based technology



- ✓ Close up of the mined-out or mine tailings area in Capayang, Mogpog
- ✓ No plants, because the soil is acidic, no essential nutrients
- ✓ Have metals such as copper, cadmium, lead and zinc (there might be more)



Eucalyptus urophylla



Acacia mangium



Pterocarpus indicus

This microbial biofertilizer technology will re-green the barren mined-out areas, and also reduce the exposure to cancer causing heavy metals.

Copper Mined Area in Mogpog, Marinduque

15 LIFE ON LAND



Previously mined for gold and copper by the Consolidated Mines Inc. through an open pit mine. The soil is highly acidic (4.6 ± 0.25) with low organic matter ($0.34 \pm 0.14\%$) and nutrient content of N, P and K ($0.22 \pm 0.02\%$, 75.5 ± 62 ppm, and 0.12 ± 0.08 me 100 g^{-1} soil, respectively). Heavy metals (HMs) and Cu content (100 mg kg^{-1} soil) exceed the maximum allowable limit of 36 mg kg^{-1} soil when compared to the Dutch standards for soil contamination assessment.

Photo by: Mar Maningas, Nov 2018

SUCCESS STORY: 6 YEARS AFTER PLANTING

- barren brown lands turned to green
- biofertilizers improved plant survival and growth of narra, *Acacia mangium* and *Eucalyptus urophylla* and *E. pellita*
- Cu and other heavy metals were concentrated in the roots of inoculated plants vs control - leaves
- Build up of microbial population



NARRA
(*Pterocarpus indicus*)



MANGIUM
(*Acacia mangium*)



EUCALYPTUS
(*Eucalyptus urophylla*)

ALREADY ADOPTED BY THE LGUs IN MOGPOG AND NON-GOVERNMENT ORGANIZATIONS IN REHABILITATING THE BARREN MINED AREAS IN MARINDUQUE

Gold Mined Areas in Placer, Surigao del Norte

The gold mined-out site in Manila Mining Corporation's tenement was characteristically acidic (pH=6.14) with low %OM matter (0.43%) and has very high Cu concentration (472.1 ± 40.4 mg kg⁻¹) which is beyond the Dutch standard intervention value- calling for an immediate rehabilitation, although other essential nutrients were moderate to sufficient.

15 LIFE ON LAND



SUCCESS STORY: 19 MONTHS AFTER PLANTING

- Survival Lahilahi 89% MogNFB, Mangkono 88% MogMYC, narra 95% Mykorich, control 40-60%
- Narra highest height and stem diameter increments MogNFB+MogMYC



NARRA

(*Pterocarpus indicus*)



LAHI-LAHI

(*Syzygium accuminatissimum*)



MANGKONO

(*Xanthostemon verdugonianus*)

Nickel Mined Area in Claver, Surigao del Norte



The nickel mined-out area of the Taganito Mining Corporation has deficient to low nutrient availability (% organic matter, total nitrogen, available P and exchangeable K) and have high nickel (7,166 ppm) content which is an order of magnitude higher than the Dutch standard intervention value of 210 ppm.

SUCCESS STORY: 29 MONTHS AFTER PLANTING

- Highest survival Lahilahi 89% MogNFB, Narra 88% MogMYC
- MogMYC increased height and stem diameter of lahilahi by 13 and 19% over Control (78.24 cm and 24.1 cm)
- Heavy metal uptakes: MogMYC highest Fe roots, Control highest (362 ppm) Ni in roots, Mykorich highest Fe and Ni in stem, Control highest (643 ppm) Fe in leaves
- Inoculation promoted microbial build up



NARRA
(*Pterocarpus indicus*)



LAHI-LAHI
(*Syzygium accuminatissimum*)



MANGKONO
(*Xanthostemon verdugonianus*)



GMAP PHASE 3 2023-2026



Marinduque (Copper)
Consolidated Mines Inc. (CMI) (not involved)

Zambales (Nickel and Chromite)
Zambales Diversified Metals Corp. (ZDMC)



Cebu (Copper)
Carmen Copper Corporation (CCC)

GMAP Marinduque

Field Planting of Native Trees in Site 1: Brgy. Ino, Mogpog (August 2023)



GMAP Marinduque

**Growth and survival at 9 months
in Cu mined area**

NARRA

Stem diameter: MogMYC, 15%

Survival: SurMYC, 100%

BANI

Stem diameter: SurMYC, 2%

Survival: SurNFB, 97%

MOLAVE

Stem diameter: MogNFB, 34%

Survival: MogMYC, MogNFB, SurMYC,
SurNFB, Control, 100%

FRINGON

Stem diameter: SurMYC, 32%

Survival: MogMYC, MogNFB, SurMYC,
SurNFB, Control, 100%

**Before
Field Experiment**



**During Field Planting
August 2023**



After 9 months



GMAP Marinduque

**Establishment of Bambusetum in the Cu mined area in Sitio Ulong,
Brgy. Capayang, Mogpog, Marinduque last September 2024**



GMAP Marinduque

Project Orientation, IEC Campaign and Lecture-Demonstration



GMAP Zambales (Ni)

Implemented by President Ramon Magsaysay State University (PRMSU) in collaboration with the University of the Philippines Los Baños (UPLB) and
Zambales Diversified Metals Corporation (ZDMC)

Survival and growth at 11 mo in the field

1. Zambales Hunggo

Survival: 99% **MogNFB**, 93% Control

Height: 3% **Mykorich** than the control (53 cm)

Stem diameter: 26% **Mykorich** over the control (1.6 cm)

2. Narra

Survival: 100% **Mykorich**, 98% Control

Height: 14% increased by **Mykorich** relative to the control (4.1 cm)

3. Bayabasin

Survival: 86% **MogNFB**, 72% Control

Height: 17% **SurNFB** taller than the control

Stem diameter: 16% **SurMYC** over the control (0.8 cm)

Planting Site: Zambales hunggo

September 2023

August 2024
(11 mo after field planting)

- Approximately **2.5 ha** field-planted with **2,500 native tree seedlings** [Zambales hunggo, narra, bayabasin, tuak (nickel hyperaccumulator)]

April 2024 (7 months)

GMAP Zambales (Cr)

Research Activities on Chromite Mined Area in Acoje

- Approximately **1.5 ha** field-planted with **1,500 native tree seedlings** (Zambales hunggo, narra, betis and white nato)
- Field planting was done in August 2024



Growth monitoring 3 (Nov 13, 2024) months after planting



GMAP Cebu



. Inoculation and growth measurements on nursery raised in narra and bamboo

GMAP Cebu

Establishment of Field Planting Sites and Field planting (2nd site)

Soil Parameters	Topsoil	Subsoil
Particle Size Analysis	Clay loam	Sandy clay loam
pH	2.38	2.71
Moisture content %	4.88%	3.71%
Organic matter (OM%)	0.28%	0.35%
Available Phosphorus (P)	18.63 ppm	16.98 ppm
Exchangeable potassium (K)	10.31 ppm	8.00 ppm
Copper (Cu)	81.03 ppm	72.15 ppm
Iron (Fe)	658 ppm	315.24 ppm

FERTILIZER RECOMMENDATION:

- Organic Fertilizer – 1 kg per seedling
- Urea – 40 g per seedling
- Potash – 25 g per seedling



People’s Organization, UPLB Research Team, and CCC Staff
in the implementation of GMAP Cebu

GMAP Cebu

Research Activities on Copper Mined Area

- Planting Site: Alahan (1st planting area)
- Approximately **2.0 ha** field-planted with **1,567 native tree seedlings** (Hambabalud, kinay and alahan)



- Planting Site: Narra (2nd planting area)
- Approximately **0.5 ha** field-planted with **900 native tree seedlings** (narra and molave)
- Additional 1,280 narra and molave seedlings planted in the 1st site



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Growth in the nursery prior to field planting and survival in the field sites

KINAY:

MYKORICH with 5% increase in height over the control

MYKORICH increased stem diameter by 67%

ALAHAN:

MYKORICH with 51% increase in height over the control

MYKORICH increased stem diameter by 17%

HAMBABALUD:

MYKORICH with 30% increase in height over the control

MYKORICH increased stem diameter by 98%

NARRA:

First batch: Height MRICH, 18%
Stem dia MRICH, 18%

Second batch: Height MogNFB, 25%
Stem dia MogNFB, 5%

Third batch: Height MogNFB, 172%
Stem dia MogMYC, 29%

MOLAVE

- Height Best MRICH 16% increase
- Stem diameter Best Sur MYC 37%

Survival in the field after one year

Hambabalud: Best SurNFB (32%), 61% higher than the control

Kinay: All dead (due to El Niño)

Alahan: Best SurNFB (60%), 43% higher than the control

Survival in the field after one month

Narra: Old site 99%
New site 90%

Molave: Old site 99%
New site 85%

ISOLATION, PURIFICATION AND SELECTION OF MYCORRHIZAL FUNGI AND NITROGEN-FIXING BACTERIA



- Promising isolates from Cu mined in Marinduque (Phase 1) were tested in Surigao Ni and Cu/gold areas (Phase 2)
- Promising isolates from Marinduque and Surigao is currently tested in Cebu (Cu), Zambales (Ni and Cr) and Marinduque (Cu) (Phase 3)
- Promising isolates from Marinduque, Surigao, Cebu, Zambales will be tested in Leyte/Samar and Palawan (Phase 4)

Ultimate Goal: To formulate inoculants for rehabilitation of mined areas irrespective of what heavy metals are present.

UNIQUE FEATURE OF GMAP



**BARREN LANDS,
NO MORE IN THE FUTURE!**



GM  **P**

**GREENING MINED
AREAS IN THE PHILIPPINES**



PHOTOS: DR. NELLY S. DICACON

ACKNOWLEDGEMENT

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COLLABORATORS

Mogpog, Marinduque

- LGUs headed by Mayor of Mogpog, Marinduque, National Police Force and 4Ps
- Mogpog National Comprehensive High School
- Barangay Capayang, Mogpog, Marinduque
- Marinduque Council for Environmental Concern (MACEC)
- Department of Environment and Natural Resources (DENR)
- Provincial Environment and Natural Resources Office (DENR-PENRO) in Boac, Marinduque
- City Environment and Natural Resources Office (DENR_CENRO) in Boac, Marinduque
- Consolidated Mines Inc. (CMI)
- Marinduque State University (MarSU)
- Department of Public Works and Highways (DPWH-Marinduque)
- Department of Science and Technology - Marinduque
- Department of Education - Marinduque

Toledo, Cebu

- Carmen Copper Corporation (CCC)
- CENRO, Cebu

Claver, Surigao del Norte

- Taganito Mining Corporation
- Mindanao State University-Iligan Institute of Technology
- Ecosystems Development Bureau-DENR, Butuan

Placer, Surigao del Norte

- Manila Mining Corporation
- Mindanao State University-Iligan Institute of Technology
- Ecosystems Development Bureau-DENR, Butuan

Sta. Cruz, Zambales

- Zambales Diversified Metals Corporation (ZDMC)
- President Ramon Magsaysay State University (PRMSU)
- CENRO, Masinloc
- PENRO, Bataan

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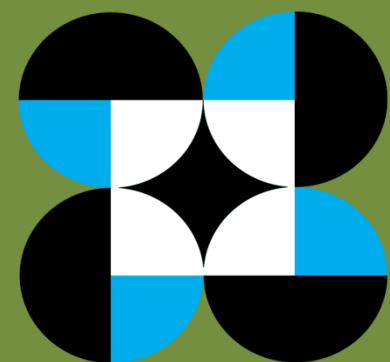
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