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Social Acceptability of the Bioremediation Technology for the Rehabilitation of an Abandoned Mined-Out Area in Mogpog, Marinduque, Philippines

ABSTRACT

Rehabilitation of mined-out areas poses great challenge because nutrients are depleted and conditions are not conducive for the conditions necessary for the growth and survival of plants. Proper combination of mycorrhizal fungi, nitrogen-fixing bacteria, compost, and lime to support the growth of trees in the poor soil has been discovered by the University of the Philippines Los Baños National Institute of Microbiology and Biotechnology. Having established a protocol using this formulation, a plant survival rate of 95% was achieved in a bioremediation project implemented by the Institute in a mined-out area in Capayang, Mogpog, Marinduque, Philippines. The social acceptance and adoption of this rehabilitation strategy was determined through a survey interview in the study area with the use of questionnaire. Six factors and nine variables were considered in the assessment. The bioremediation technology was acceptable to the community as indicated by the high percentage of respondents who gave an overall positive response (90%) and who were willing to adopt and recommend it for implementation in other mined-out areas (90%). Binary logistic regression showed that income and distance of residence from the rehabilitation site significantly influenced the respondents' decision to accept the technology. Future bioremediation initiatives should also consider the participation and acceptance of stakeholders to ensure sustainability. Indigenous and endemic planting materials should be used in rehabiliation.

Keywords: *social acceptability, bioremediation technology, mined-out area rehabilitation, Mogpog, Marinduque*

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INTRODUCTION

A holistic approach to successful application of environmental management or technologies is the consideration of all necessary aspects, which include the social dimension of projects. Many studies that relate to the use of technological innovations for rehabilitation or management efforts highlight the importance of understanding and recognizing the role of community to attain success. This is because the community residents are among the primary stewards of natural areas since they have the knowledge and direct contact with the local environment. Moreover, they are the ones directly affected or benefitted by any intervention introduced in their area.

Similarly, to meet the objectives of ecosystem management, *Shindler et al.* (*2004*) stressed that implementors should not only understand how natural systems function and sustained, but should also consider how people interpret and respond to changes in forest settings, policy decisions, and management institutions. Engaging the community through participative processes that would allow for informed and sustainable decisions to merit long term positive effects has also been noted by *Appelstrand* (*2002*). This implies that if people have a stake in a particular activity, they are likely to accept and extend support for the sustenance of projects. As societal issues or controversies about a technology may cause the rejection of its application or commercialization, public acceptance has been a critical concern found to influence the success of projects. *Shindler et al.* (*2004*) also reckoned public acceptance as important in relation to the avoidance of uncertainties in adapting ecosystem-based approaches and of the conditions resulting from forest management practices. *Shindler et al.* (*2004*) recounted the findings of two studies whereby both acknowledge the fundamental notion that even if policies and practices are profitable and supported by science, they will ultimately fail if they lack the acceptance and approval of society.

Social acceptability was found to be influenced by several factors other than the participation of stakeholders. *Gupta et al.* (*2011*) reviewed almost 300 published articles that delved into the determinants of public acceptance of technologies. *Gupta et al.* (*2011*) found that trust, risk, knowledge, perceived benefits, individual differences, and attitude have been the focus of majority of these researches. *Ford et al.*'s (*2014*) concept of public acceptability judgments of environmental management also suggests that acceptability is influenced by people's value orientations in view of beliefs or perceptions on the risks, impacts, and benefits of the technology/project, scenic quality, trust among the project implementors and cooperating agencies, and knowledge about the project. Similarly, *Kakoyannis et al.* (*2001*) also considered trust, risk, knowledge, public values, and beliefs as crucial when aiming for social acceptability. In line with this, they also described the influence of social context on people's judgment towards acceptability. They observed that demographic characteristics, which include gender, age, education, income, and residence, can affect how people value the environment.

Weir (*2015*) also associated the acceptability of phytoremediation technology with the direct involvement of participants in discussions. *Balasubramanian et al.* (*2007*) as cited by *Weir* (*2015*) found that "acceptance of remediation options can increase when the public is involved in decision-making". *Weir and Doty* (*2016*) shared the same observation for remediation projects and asserted that social acceptability assessments can be valuable tools to determine if these projects will become viable. They explored the social acceptability of phytoremediation strategies used to remove polycyclic aromatic in a public park which was formerly a gas production site. Responses during the assessment revealed the overwhelming positive perceptions about phytoremediation and the strong support for its implementation at the park. Risk, knowledge, trust, values, ownership and participation, and landscape preference were found to have greatly influenced the acceptability of the phytoremediation strategy.

Bioremediation is an innovative technology that relates to the transformation or degradation of contaminants into less or non-hazardous substances with the aid of microorganisms (*Karigar and Rao 2011; Vidali 2001*). These are bacteria, algae, or fungi that are already living in the soil or water (*Vallero 2011*). They decontaminate polluted soil, water, or sediment to make them safer for use. Bacteria that are within plants, such as endophytes, also provide beneficial relationships with host plants (*Bulgarelli et al. 2013*) to help enhance the remediation capabilities of plants. Phytoremediation, a type of bioremediation, involves the use of plants to naturally remove organic and inorganic contaminants. Aside from being less expensive compared to other methods, it is considered more aesthetically pleasing because it uses plants, more beneficial to animals by providing habitat, and stabilizes soil and contaminants (*Doty 2008*).

Bioremediation protocols using mycorrhizal fungi and nitrogen-fixing bacteria for the rehabilitation of copper-rich mine tailing areas have been developed by the National Institute of Microbiology and Biotechnology (Biotech) in the University of the Philippines Los Baños (UPLB), College, Laguna, Philippines. Mine-tailing areas are very acidic and depleted with nutrients that are necessary for plant growth and survival; hence, lime and compost were added. In a news article by the National Research Council of the Philippines, Aggangan (*2017*) explained that it works through "a symbiosis that exists between the fungus and the root of the host plant. The fungus colonizes the root system, facilitating increased water and nutrient uptake while the plant provides the fungus with carbohydrates as food which is formed during photosynthesis". The fungus also increases the plants' tolerance to environmental stresses, including heavy metals that are present in mined-out areas.

Using the protocols, UPLB Biotech has implemented the project, "Bioremediation Strategies for Rehabilitation of Abandoned Mined-Out Area in Mogpog, Marinduque", in 2015 with the cooperation of the Local Government Units headed by the Mayor of Mogpog, Marinduque; Mogpog National Comprehensive High School; Barangay Capayang, Mogpog, Marinduque; and the Department of Environment and Natural Resources Provincial Environment and Natural Resources Office and City Environment and Natural Resources Office in Boac, Marinduque. With bioremediation technology, a plant survival rate of 95% was achieved. This has complemented with the local government's interest of saving the province's natural resources that were nearly destroyed by several decades of mining activities. Aside from the technology, success may also be associated with the participation and acceptance of the community.

During the earlier stage of implementation, it was observed that some of the residents had a negative attitude towards the project. It was reported that the narra (*Pterocarpus indicus*) trees planted in the site were harvested for charcoal production. When the residents were hired and even duly compensated for their participation, particularly in planting, tending, and maintaining the area, they became cooperative and tended to show concern about the project. However, it is deemed necessary that the acceptance and adoption of the bioremediation technology/protocol by the stakeholders should be assessed. This will enhance their participation and ensure their support to maintain and protect the project. This will also serve as basis for project implementers as to what aspect the technology or intervention would require further attention for improvement. This study was conducted to determine the level of acceptance of the community and their willingness to adopt and recommend the rehabilitation technology. The factors and the relationship of the different variables that affect their acceptability were also assessed.

MATERIALS AND METHODS

The Study Site and Data Collection Methods

The social acceptability assessment of the bioremediation technology/protocol for the rehabilitation of some portions of the 32-ha mined-out dumpsite was conducted in Barangay Capayang, Mogpog, Marinduque, Philippines (**Figure 1**) in 2018. Mogpog is a 3rd class municipality in the Province of Marinduque. It is composed of 37 barangays, including Capayang where the study site is located. Capayang was a mining area operated by Consolidated Mines, Inc. (CMI) *(Ilagan 2009 as cited by Fontanilla 2010*). In 1995, a pond with mine tailings accidentally broke down and contaminated the Boac River and its surroundings causing these to become barren for more than three decades.

Using purposive sampling, the respondents of this study were households of the impact barangays; representatives from the local government unit (LGU); government agencies, such as the Department of Environment and Natural Resources (DENR), Department of Agriculture (DA), and Department of Health (DOH); and academic institutions including school teachers and students. Interviews with the aid of questionnaire were done in May 2018. Household members of legal age (at least 18 years old) were considered as respondents in the absence of the household heads. The sample size was determined through the Slovin's Formula as follows:

$$n = \frac{N}{1 + Ne^2}$$

where: n = sample size
N = total number of households
e = margin of error at 10%

In 324 households, the sample size was 76. However, a total of 145 respondents were interviewed to

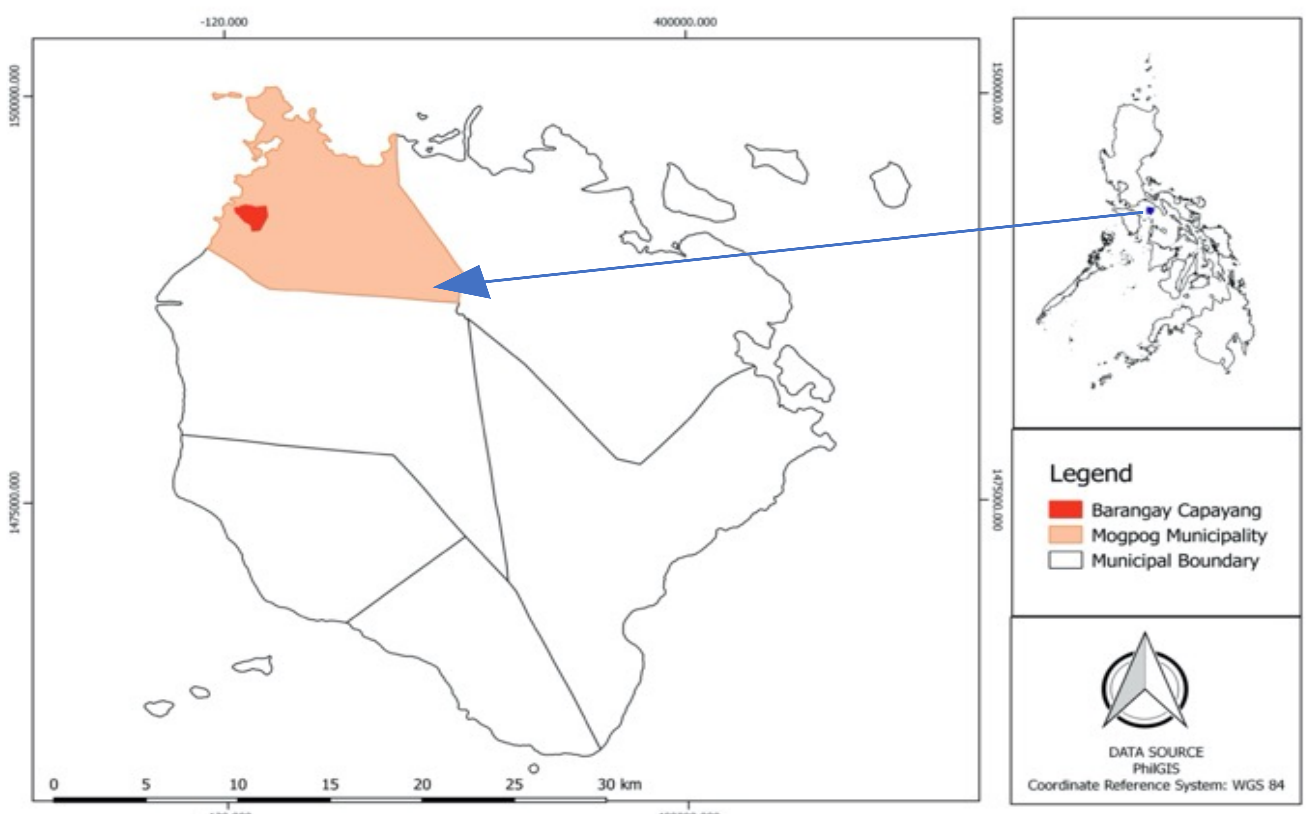

Figure 1. Study site for the determination of social acceptability of the bioremediation technology/protocol for the rehabilitation of the mined-out area in Barangay Capayang, Mogpog, Marinduque, Philippines, 2018.

obtain more relevant information, ideas, perceptions, and recommendations from other respondents who were willing to contribute in the conduct of the study.

During the Technology Forum on "Microbial Inoculation for Mined-Out Area in Mogpog, Marinduque" conducted in Barangay Boac on May 29-30, 2018, the bioremediation technology and the rehabilitation project were discussed by the project implementers. Some of the participants were respondents of this study. After the forum, the participants were brought to the study area to personally see the site that is undergoing rehabilitation. For the respondents who were not able to attend the Forum, the bioremediation technology and rehabilitation project were explained to them during the interview. Photographs of the area depicting its past and present appearance/condition were shown whenever necessary.

A pre-tested structured questionnaire, along with an Informed Consent Form, was used for the interview. The questionnaire was composed of six parts: Socio-Demographic Information; Description of the Past and Present State of the Mined-out Area; Social Acceptability of the Bioremediation Strategies of the Rehabilitation of the Abandoned Mined-out Area; Respondents' Comments and Recommendations; Overall Response; and Future Visioning of the Area. The questionnaire and Informed Consent Form were written in Tagalog- the dialect in the study area.

Prior to the interview, the objectives of the activity and the contents of the Informed Consent Form were explained to the respondents. The respondents were requested to read and sign the Form to signify their willingness and voluntary participation in the interview.

Data Analysis

Determination of the social acceptability was adopted from the concept of social acceptance of technologies using some of the most widely studied factors (*Gupta, et al., 2011; Weir and Doty 2016*). It is also anchored on the concept of public acceptability of environmental management by *Ford et al.* (*2014*) as influenced by several other studies. The model connotes that acceptability is predisposed by value orientations in terms of beliefs or perceptions on the risks, impacts, and benefits of the technology/project, scenic quality, trust among the project implementors and cooperating agencies, and knowledge about the project.

Descriptive statistics was employed in the analysis of data gathered from the interview survey. Cross tabulation and calculation of the percentages and frequency distributions were done using the SPSS Software (Statistical Package for the Social Sciences). The relationship of the different variables that affect the social acceptability of the bioremediation technology was also analyzed using binary logistic regression.

RESULTS AND DISCUSSIONS

A total of 145 respondents were interviewed distributed as follows: household members (90 or 62%); students and teachers (37 or 26%); Local Government Unit employees (16 or 11%); government employees from the Department of Environment and Natural Resources and the Department of Science and Technology (2 or 1%).

About 26% of the respondents were between the ages 41 and 50 years; 22% were below 20 years old; and 21% were between 31 and 40 years old. The average age was 39 years. Male respondents dominated (75%) the females (25%) and almost 60% were married. Most of them made it to the high school level (32%), around 11% were pursuing college education, while 9% were already graduates. Nearly half of the respondents had been residing in the area for at most 20 years (46%) and only 8% of them had been there for 61 to 80 years since their birth.

Most of the respondents (31%) were earning a monthly household income ranging from PhP 1,000.00 – PhP 5,000.00. Only a few (9%) had an income greater than PhP 20,000.00. Some respondents did not reveal their income (18%). A large percentage of the respondents had been engaged in their present occupation for more than 10 years (34%). Many of them did not disclose information regarding their present occupation (25%). Majority of the respondents were living with 3 to 5 members in their household (52%).

Description of the Past and Present State of the Mined-out Area

After the area in Barangay Capayang had been mined out, it was left barren for more than 30 years. This was confirmed by the interview conducted with the local residents wherein 80-90% of them recalled that the area used to be barren, unproductive, eroded, and contaminated (**Table 1**). About 70-89% of them also agreed that sinkholes emerged, biodiversity decreased, water quality deteriorated, and water resources depleted. Some of them observed that the water in some parts of the community turned blue in color and caused skin irritations.

Table 1. The past and present state of the mined-out area in Capayang, Mogpog, Marinduque, Philippines as described by the respondents in the social acceptability study of the bioremediation technology by the University of the Philipines Los Baños National Institute of Microbiology and Biotechnology, 2018 (n=145).

Issue	Past State of the Mined-out Area					
	Agree		Disagree		No Answer	
	Frequency	%	Frequency	%	Frequency	%
Unproductive Land	116	80	25	17	4	3
Eroded	129	89	8	6	8	6
Presence of Sinkholes	104	72	30	21	11	8
Biodiversity Loss	125	86	13	9	7	5
Contaminated Soil	131	90	8	6	6	4
Depleted Water Resources	112	77	25	17	8	6
Deteriorated Water Quality	129	89	8	6	8	6
Barren Area	131	90	8	6	6	4
Issue	**Present State of the Mined-out Area**					
	Agree		Disagree		No Answer	
	Frequency	%	Frequency	%	Frequency	%
Unproductive Land	15	10	83	57	47	32
Eroded	24	17	69	48	52	36
Presence of Sinkholes	23	16	59	41	63	43
Biodiversity Loss	19	13	67	46	59	41
Contaminated Soil	23	16	64	44	58	40
Depleted Water Resources	21	14	66	46	58	40
Deteriorated Water Quality	28	19	58	40	59	41
Barren Area	25	17	62	43	58	40

In 2015, a bioremediation strategy was implemented by the UPLB Biotech using forest tree seedlings inoculated with a combination of fungi and nitrogen-fixing bacteria, compost, and lime before they were transplanted to the mined-out site. Using the technology, the seedlings were found to have significantly higher survival rate compared to the seedlings planted in soil without amendments. With the bioremediation project, the area now displays a lush growth of forest trees in the degraded land (**Figure 2**). This is due to the beneficial fungi and bacteria that helped strengthen the plants' tolerance to high acidity and heavy-metal-laden soil (*Aggangan et al., 2017*). The trees planted were *Pterocarpus indicus* (narra), *Acacia mangium* (mangium), and *Eucalyptus globulus* (eucalyptus).

These positive impacts of the bioremediation project on the physical condition of the site were remarkably recognized by the resident-respondents. Only 10-19% among them agreed that the poor condition of the area is still the same. This implies that majority of them noted a significant improvement in the area. However, it is also worthy to note that, although they were presented photographs of the area, a high percentage (32-43%) cannot describe the present condition of the site as they have not visited the area since the rehabilitation was implemented.

Figure 2. Portion of the mined-out area being rehabilitated in Capayang, Mogpog, Marinduque, Philippines using the bioremediation technology of University of the Philipines Los Baños National Institute of Microbiology and Biotechnology, 2018.

Factors Affecting the Social Acceptability of Bioremediation Strategies

Social acceptability can be associated with attitude judgement to the impact of a particular project. Based on judgement, people can compare the perceived existing real condition of the environment with its known alternatives and by which they will decide if the real present condition is the most favorable alternative or not (*Brunson 1996*). The judgment may serve as the basis on accepting the project and may result to positive responses for management actions (*Ford et al. 2009*). Studies indicate that direct and active participation of affected communities and other stakeholders can influence social acceptability of technologies or projects. Participative processes are considered to deliver informed decisions that lead to positive actions with long term results hence, sustainability of the project. Social acceptability also varies with people's beliefs, trust (*Ford et al. 2014; Gupta et al. 2011*), values, aesthetic experience (*Ford et al. 2014*) risks, knowledge, individual differences, and attitude (*Gupta et al. 2011*).

Participation in the Project

Among the 145 respondents, 44% were involved in the rehabilitation project. Some were hired as laborers particularly in the digging of holes in preparation for the planting of the inoculated seedlings in the mined-out site. Others took the task of watering the plants while some helped in maintaining and patrolling the area to guard the plants from being damaged or stolen. While majority of the respondents did not participate in the project activities (56%), 131 or 90% of the total respondents gave positive response in terms of the acceptability of the technology/ project.

Value Orientations

Values are influential in judging environmental management initiatives (*Ford et al. 2014*). This suggests that people's value orientations affect their decisions to approve actions especially those that will impact them. The respondents recognized the importance of trees or forests for the people and for the environment thus, they regarded the use of the bioremediation technology in their area beneficial. Almost all of them concurred with the importance of trees/forests for recreation and hobbies (94%). Some of them expressed appreciation on the value of trees in providing shade and cool air where they can spend time to rest, relax, or play around. They also considered these vital in the sustenance of ecosystems or the environment (99%), important for future generations (99%), and effective barrier against calamities (97%), such as typhoons and landslides (**Table 2**).

Scenic Quality

Scenic quality is the value of the viewed landscape based on its perceived visual attractiveness as determined by the aesthetic composition of the visual elements (*Meyer 2016*). High quality sceneries actually tend to attract people and enhance their experience in an area. In forest planning, scenic quality is recognized as another important variable for assessing environmental factors (*Ward and Snoberger 2009*). Efforts to address acceptability have been historically focused on scenic quality when it comes to forest management and research (*Brunson et al. 1996*).

Table 2. Factors affecting the social acceptability of the bioremediation technology of the respondents in Capayang, Mogpog, Marinduque, Philippines, 2018 (n=145).

Factors	Agree		Disagree		No Answer	
	Frequency	%	Frequency	%	Frequency	%
Participation						
Participated in any of the activities in the implementation of the bioremediation project	64	44	81	56	0	0
Value Orientations						
The forests are important for recreation and hobbies	137	94	5	3	3	2
The forests are vital in the sustenance of ecosystems/environment	143	99	1	1	1	1
The forests are important for future generations	143	99	0	0	2	1
The forests are effective barriers against calamities	141	97	1	1	3	2
Scenic Quality						
The landscape of the area has improved after it has been planted with trees	141	97	3	2	1	1
The productivity of the land has improved	137	94	5	3	3	2
The environment became green/greener	136	94	3	2	6	4
Beliefs on the Impacts and Benefits of the Bioremediation Technology						
Socio-Economic Aspect						
The project is improving the quality of life of residents	135	93	5	3	5	3

Table 2. Factors affecting the social acceptability of the bioremediation technology of the respondents in Capayang, Mogpog, Marinduque, Philippines, 2018 (n=145). (cont.)

Factors	Agree		Disagree		No Answer	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
The project has created/is creating employment/livelihood opportunities	130	90	9	6	6	4
The project has fostered cooperation and participation between and among residents and relevant agencies in relation to natural areas conservation	134	92	8	6	3	2
The project encourages the revival of cultural traditions and values.	132	91	5	3	8	6
Health risks are reduced because of the project	134	92	6	4	5	3
The project has increased the awareness of residents regarding the importance of a balanced and healthful ecology	141	97	1	1	3	2
The benefits of the project are widely distributed among the stakeholders	118	81	14	10	13	9
Environmental Aspect						
Water						
The project is important in improving the supply of quality and sufficient water resources in the area	139	96	4	3	2	1
Habitats of many living organisms are provided	141	97	1	1	3	2
Conservation of water plants and animals are promoted	141	97	0	0	4	3
Soil						
Risks of soil erosion and degradation are prevented/minimized	143	99	0	0	2	1
Floods are prevented/minimized	137	94	3	2	5	3
Biodiversity in the area and its surrounding environment is increased	141	97	2	1	2	1
Conservation of terrestrial plants and animals is supported	138	95	3	2	4	3
Air						
Pollution gases, odors, and particulate matters are filtered	141	97	2	1	2	1
Supply of oxygen is enhanced.	138	95	4	3	3	2
Conservation of air animals is supported	141	97	2	1	2	1
Atmosphere/Air becomes cooler	135	93	5	3	5	3
Health						
The incidence of people getting sick is reduced.	137	94	5	3	3	2
Mortality rate of is decreased.	111	77	25	17	9	6
Spread of diseases is reduced.	130	90	8	6	7	5
Knowledge about the Project						
The use of mycorrhizal fungi and nitrogen-fixing bacteria for bio remediation is a cost-effective strategy in rehabilitating mined-out areas.	139	96	3	2	3	2
The project is a fast and effective solution to reduce/eliminate the toxicity from mine-tailings.	139	96	1	1	5	3
There are no risks associated with the use of the technology to implement the project.	133	92	7	5	5	3
Trust in Cooperating Agencies and Project Implementors						
The cooperating agencies and project implementers are trustworthy institutions.	138	95	2	1	5	3
The project implementers are always considering the interests and opinions of the community people.	139	96	1	1	5	3
The project implementers have effectively communicated the project and its objectives to the community.	138	95	3	2	4	3
The community people actively support the implementation and sustenance of the project.	128	88	11	8	6	4

Based on the survey of this study, majority of the respondents (97%) agreed that the landscape of the area has improved after it has been planted with trees. Respondents also believed that the productivity of the land has improved (94%) and that the area became greener (94%). Having personnaly seen the area and by looking at the photographs of the site, they were stunned of its significant transformation "from brown to green".

Beliefs on the Impacts and Benefits of the Bioremediation Technology

One important aspect considered in determining the social acceptability of the project is its socio-economic impacts. The use of the technology relates to the successful conversion of unproductive or barren lands into productive lands. This translates to the upliftment of the socio-economic conditions of the local communities and the enhancement of the environmental values of the area. However, the tangible benefits of the bioremediation/ rehabilitation project are not readily apparent to the local communities during the establishment phase. The trees have to be established and well maintained for at least 25 years to achieve utilizable age and significant long term benefits. Nonetheless, majority of them (81%) stated that they have already benefitted from the project. Some of them were hired laborers who assisted in the digging of holes where the seedlings were to be planted, in tending, and in maintaining the plants (**Figure 3**). Others claimed that although they were not engaged as hired laborers, they believed that the trees provide them indirect benefits, such as improvement of soil fertility, reduction of soil erosion, enhancement of aesthetic value, improvement of water quality, provision of cool air and healthy environment, among others.

Furthermore, almost all of the respondents (91-97%) treated the technology/project as a solution to environmental problems, source of livelihood opportunities, reduction of health risks, revival of cultural traditions and values, and increased awareness on the importance of a balanced and healthful ecology. Respondents also believed that the project was able to convene the people together for a common cause through the participatory approach that was promoted between and among the residents and concerned agencies for the restoration and conservation of the natural resources in their community (92%).

Figure 3. Local residents involved in planting for the rehabilitation of a mined-out area in Mogpog, Marinduque, Philippines, 2018.

Another important factor that could influence social acceptability is the perceptions on the potential environmental impacts of the project. Discussions are categorized based on the perception of respondents in terms of four domains: water; soil or land; air; and health.

Perceived Effects on Water Quality and Sufficient Water Supply. *Tetra Tech EM, Inc.* (*2001*) reported that the land and water bodies near the abandoned mine sites in the Philippines are impacted with chemical contaminants which may harm human health as well as the health of aquatic, terrestrial, and wildlife species (*Fontanilla and Cuevas 2010*). The bioremediation technology, according to majority of the respondents (96%), could help in improving water quality and in providing sufficient water supply for the community. They believed that the trees grown can help prevent soil erosion and surface runoff and can uptake and store contaminants, thus water bodies are prevented from contamination or degradation. Considering these, 97% of the respondents believed that favorable habitats for organisms are consequently provided, thereby, conservation of biodiversity is also promoted (97%). Some of them recalled that no fish could thrive in the nearby lake; however, some fish species [e.g., *Oreochromis niloticus* (tilapia)] are now proliferating in the water body.

Perceived Effects on Soil/Land. Since the micorrhizal inoculants are natural components of plants, these are perceived to have no adverse effect on the soil or land. These actually help improve soil condition (*Aggangan et al. 2017*) and stabilize the soil and contaminants (*Weir and Doty 2016*). With micorrhizal inoculants applied with the seedlings, they grew into trees faster and more robust. Respondents were aware that these trees have important functions (99%). Among these include the prevention or reduction of soil erosion by protecting the soil from the impact of rain and by absorbing and storing water through their root systems. One reason is the fungi in the inoculants that colonize the root system of the plants enabling accelerated water uptake. Around 94% of the respondents believed that erosion and flooding are prevented or minimized in areas where trees are planted.

Trees are also important components of biodiversity since they provide habitat for many living organisms. It has been reported that a single tree in a tropical rainforest can house up to 2,000 different species of insects, reptiles, birds, amphibians, mammals, fungi, and epiphytic plants (*Suratman and Latif 2020*). The respondents believed that biodiversity in the area and its surrounding has increased (97%) and that conservation of terrestrial plants and animals is supported (94%) because living organisms are provided with the natural environment necessary for sustenance and reproduction.

Perceived Effects on Air Quality. The respondents believed that the bioremediation technology does not endanger the quality of air since it is made of natural elements. Respondents viewed its effect on air positively because of the benefits that can be derived from the trees that grow fast in the mined-out area because of the technology. Respondents considered trees as vital in improving air quality as they are known to absorb carbon dioxide and other potential harmful gases, such as sulfur dioxide and carbon monoxide.

Almost all of the respondents agreed that the trees planted in the study area filter pollution gases, odors, and other particulate matters (97%). About 95% also believed that supply of oxygen is enhanced since many additional trees have been planted in the site. One commonly cited statement indicate that one large tree can provide a day's supply of oxygen for four people (*Arbor Day Foundation n.d., NCSU n.d., Stancil 2019, Tree Canada, n.d.*). In an urban setting, *Nowak et al.* (*2007*) reported that a hectare of tree cover can provide 20 people with enough oxygen depending on tree density, diameter distribution, tree health, and tree growth.

Perceived Effects on Health. The mining activities did not only damage the environment but also endangered the health of the local residents because of the toxic chemical leakages that it has produced. Trees are important in such situations as these are good interceptors of harmful particulate matters which are contributory to many respiratory diseases (*Nowak et al. 2014*). It is in this regard that the respondents viewed the bioremediation technology as a means to help improve human health because of the trees grown in the site.

The local residents also agreed that the incidence of people getting sick in the community is reduced after trees have been planted in the mined-out area (94%). About 90% also said that spread of diseases, such as skin and respiratory disorders, was reduced. One mining-related accident was recalled by some respondents; however, respondents could not provide details about this. Around 77% of the respondents agreed that mortality rate is decreased although they could not relate the death of residents to the mining operations.

Knowledge about the Bioremediation Technology

Questions related to the knowledge of the respondents about the bioremediation technology and the rehabilitation effort included information about the project, the project's effectiveness to rehabilitate the mined-out area, the possible negative effects and the risks involved in its application in the study site. Some of the respondents were already aware of the technology and the on-going project because their involvement in some of the activities. Respondents also had previously attended a meeting and discussion about the technology/project held at the barangay hall. Almost all of the respondents concurred that the UPLB Biotech bioremediation technology is a natural rehabilitation strategy that is affordable (96%). A kilogram of the soil-based fertilizer that contains the mychorrhizal fungi costs only PhP 100 (less than US$ 2.00). This can inoculate 200-400 plants; and treatment entails only one-time application.

Some also stated that the rehabilitation project is a fast and effective solution to reduce or eliminate toxicity from mine tailings (96%). The lack or slow growth of plants in contaminated soils has been identified as a limitation in bioremediation efforts since these kind of sites are depleted from nutritients and good soil structure that would hold the water and nutrients that are necessary for plants (*Rayu et al. 2012*). However, it was evident that the trees planted in the study site were flourishing. Those who were involved in the planting stage also attested that the trees have grown fast within a 22-month period (**Figure 4**).

Sjoberg (*2002*) explained that people are assumed to resist a certain technology because of the risks involved in its application. Thus, studies recognize the importance of perceived risk in discussions of attitudes toward technologies. In this survey, 92% agreed that there are no risks or negative effects associated with the use of the bioremediation technology that was developed by UPLB Biotech. Respondents reasoned that the technology used natural elements and has no harmful chemical components; hence it is safe for human, animals, plants, and the environment. Moreover, since trees/plants, insects, and other living things are now thriving in the site, they considered this as an indication that the technology is risk-free. With these, respondents believed that the technology poses no harm but actually helps in

Figure 4. Trees planted in the mined-out area in Mogpog, Marinduque, Philippines using the bioremediation technology of the University of the Philipines Los Baños National Institute of Microbiology and Biotechnology, 2018.

cleaning waste from mining for a safer environment for their community.

Aggangan et al. (*2017*) reported a similar study on the use of mycorrhizal inoculation (with combination with lime and compost) of Jatropha curcas for the bioremediation of a mine tailing area in the same study site. The mycorrhizal treatment was found to increase the root barrier of Jathropa against heavy metals thus, may inhibit the translocation of Cu, Pb, and Zn from roots to seeds. This indicated that the oil from *Jathropa curcas* seeds is risk-free and safe as source of bioenergy.

Nonetheless, the respondents also cited that, in any case the remediation technology would pose some negative effects, they suggested the following measures: temporarily stop the technology for further study; stop the implementation of the technology; and ask the concerned agency to provide alternative technology.

Trust in Cooperating Agencies and Project Implementors

Ellis and Ferrero (*2016*) explained that mutual trust between communities, implementors, and state institutions is an important component of any engagement process and for the public or community to ultimately accept the legitimacy of decisions. This is also applicable in regard to the decision of the community to accept the bioremediation technology.

Majority of this study's respondents agreed that the cooperating agencies and project implementors are trustworthy institutions (95%). Respondents also believed that the project implementors have always considered the interests and opinions of the community people and have successfully translated the objectives of the project to the community (96%). According to them, the community people were invited to the barangay hall to attend meetings and seminars about the biomediation technology and the rehabilitation project.

As an indication that they trust the agencies and project implementors, around 88% of the respondents signified support for the sustainability of the project. Respondents also expressed gratitude to the different agencies involved in the project for choosing their community as the study site as they now benefit from the trees that were planted using the bioremediation technology. The respondents recognized the time, effort, and dedication of the agencies and implementers who even had to "regularly travel a distance to implement and monitor the development project in their community". Respondents were also confident that since the project implementers have conducted studies about the technology, they believed that they are experts or specialists who are knowlegeable enough in carrying out the project appropriately.

It was evident that the respondents demonstrated high level of positive responses on all the questions related to: value orientations (94-99%); scenic quality (94-97%); beliefs on the impacts, risks, and benefits of the project (81-99%); trust in agencies and project implementers (88-96%); and knowledge about the project (92-96%). Only 44% were engaged in the project; nonetheless, 90% accepted and were willing to recommend the technology/ project (90%) including those who did not participate in its implementation (**Figure 5**). These imply that the respondents perceived the project to be satisfactory and have met their expectations that it will deliver its potential in helping their community recover from the negative effects of mining.

Binary Logistic Regression

This study analyzed the relationship of different variables on the social acceptance of the bioremediation technology using binary logistic regression. The model was found to be highly significant at 1% level and the variables considered were good representation of the determinants of the dependent variables. Nine variables were considered in the equation: age, gender, nationality, civil status, education, years of stay in the area, income, years of involvement in the bioremediation technology, and distance of residence from the rehabilitation/ bioremediation site. Among the nine variables, income

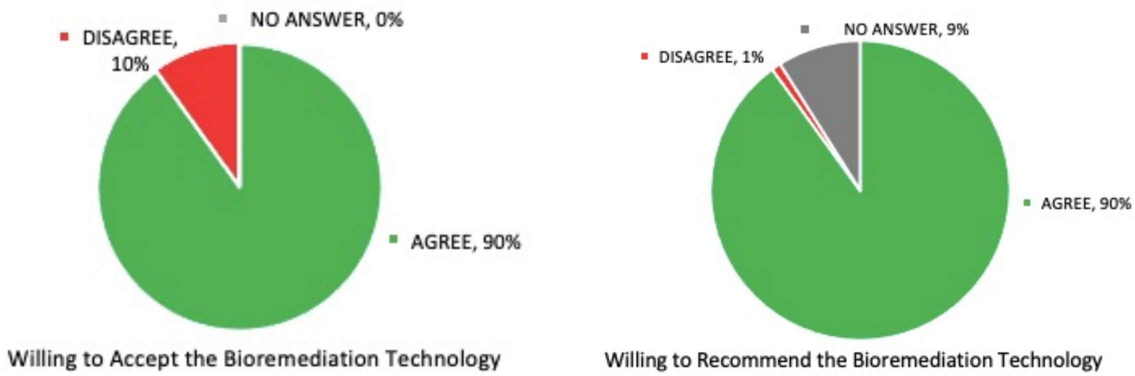

Figure 5: Social acceptability of the bioremediation technology of the University of the Philippines Los Baños National Institute of Microbiology and Biotechnology implemented in Mogpog, Marinduque, Philippines, 2018 (n=145).

and distance of residence from the rehabilitation site were the two variables found to have significantly influenced the decision of the respondents to accept the bioremediation technology (**Table 3**).

Income was a variable found to be significant at 10%. This implies that for every one unit decrease in income, the "odds of the combined high and middle rank" of social acceptance is 0.655 times higher holding all other independent variables constant. This could be associated with the behaviour of some people with lower income to likely accept and adopt the technology because of expectations that it could provide livelihood and help augment their income. Respondents perceived that this can be achieved because the productivity of the land will be improved. Similar result was presented by *Espaldon et al.* (*2016*) that charcoal producers with lower income were more likely to adopt sustainable charcoal production practices. *Muzari et al.* (*2012*) also found that income (in addition to assets, institutions, vulnerability, awareness,

Table 3. Binary logistic regression of the variables affecting the social acceptability of the bioremediation technology in Capayang, Mogpog, Marinduque, Philippines, 2018 (n=145).

Variables in the Equation							
		B (coefficient)	**S.E. (Standard Error)**	**Wald**	**df (degrees of freedom)**	**Sig.**	**Exp(B) (Odds Ratio)**
Step 1[a]	Age	-.013	.033	.168	1	.682	.987
	Male	-16.596	69616.292	.000	1	1.000	.000
	Female	.032	.732	.002	1	.965	1.033
	Foreign			.000	1	1.000	
	Filipino	-18.597	40193.016	.000	1	1.000	.000
	Civil Status (Single)	-.490	45970.410	.000	1	1.000	.613
	Civil Status (Married)	-18.534	22311.518	.000	1	.999	.000
	Civil Status (Widowed)	-17.680	22311.518	.000	1	.999	.000
	Civil Status (Divorced/Separated)	-17.853	22311.518	.000	1	.999	.000
	Civil Status (Live-in)	-20.096	22311.518	.000	1	.999	.000
	Education	.215	.196	1.197	1	.274	1.240
	Years in the Area	.011	.024	.210	1	.647	1.011
	Income	-.423	.248	2.910	1	0.08*	.655
	Years Involved in Bioremediation	.232	.363	.410	1	.522	1.262
	Distance from Bioremediation Site	1.005	.458	4.822	1	0.02**	2.731
	Constant	38.327	45970.480	.000	1	.999	44160969465785400.000

[a]Variable(s) entered on step 1: Age, Sex, Nationality, Civil Status, Education, Number of Years in the Area, Income, Years of Involvement in the Bioremediation, Distance of Residence from Bioremediation Site

labor, and innovativeness) affects the decision to adopt technology by smallholder farmers.

The distance of residence from the bioremediation project was also found to have significantly influenced social acceptance. The result of the regression test revealed that the farther the respondents reside from the rehabilitation area, the more that they accept the technology or project. This could be attributed to insights that since they are distant from the area, they are unlikely to be affected by the activities and the consequences of these. Those who were residing near the rehabilitation site also accepted the technology maybe due to the perceived direct positive impacts of the project, which include reduction of soil erosion and flooding, and improved land productivity.

Respondents' Recommendations to Improve the Use of Bioremediation Technology

The respondents suggested the continuous planting of trees in the mined-out area. Respondents recommended the use of the bioremediation technology because it aids the plants to easily thrive and grow fast in the barren area. According to 89% of the 145 respondents, the tree species planted in the site were appropriate; however, the respondents also recommended indigenous plants, fruit trees (e.g., mango and coconut), gmelina (*Gmelina arborea*), ipil-ipil (*Leucaena leucocephala*), and bamboo (*Bambusa* sp.). Bamboos were also recommended to be planted along the riverbanks. The respondents also suggested planting of edible plants in the study site.

The respondents also suggested that the water quality of the lake near the mined-out area be analysed to have the basis for appropriate action in relation to its safety for the community. This was suggested since it was reported that some residents were catching fish from the lake probably for consumption.

Respondents also proposed that the community people should be educated about the importance of rehabilitating the area, particularly on land productivity, health benefits, reducing/preventing soil erosion, and enhancing aesthetic value, among others. This will also help promote forest conservation, proper waste disposal, and other environmental awareness. To protect the plantation against illegal cutting, the respondents suggested that participation and cooperation among the community and other stakeholders should be engaged. This can help attain the community's support to the project to ensure its sustainability.

Future Visioning of the Area

Although bioremediation proves to be effective in cleaning-up mined-out sites, all of the respondents opposed any future mining operations in their community. Some called for the total closure of all mining activities in order to stop further environmental damages. Respondents said that life is better off without the threats from mining which, according to them, are haunting them up to the present.

Most of the respondents particularly mentioned the restoration of their area into its past condition. Respondents related that their community used to have clean water and fresh cool air due to the proliferation of trees and plants prior to the mining operations. They expressed regret that water in some areas of the community is still unsafe for use and consumption due to the mining operations in the past. Respondents showed distress over the current situation of their community and are hopeful for its fast recovery with the help of the on-going rehabilitation of the mined-out areas.

CONCLUSIONS AND RECOMMENDATIONS

The bioremediation technology offers a promising solution in rehabilitating mined-out areas and in addressing environmental damages caused by mine tailings. It also gained the high level of acceptability and willingness of the local community to adopt and recommend it for implementation in similar areas. This includes those who were not engaged in any activity related to the implementation of the project. It denotes that the respondents acknowledged the viability of the technology and accepted it whether they were involved in the project or not. Decision to accept was associated with the respondents' income and distance of residence from the rehabilitation site. Some respondents with lower income expected livelihood when productivity of the land will be improved. Those residing farther from the rehabilitation area also accepted the technology more. This could be attributed to the perception that these residents are less likely to be affected by the project activities and impacts. Acceptance of the technology by respondents near the site could be due to the positive impacts perceived to directly gain benefits from, e.g., reduced soil erosion and flooding, and improved land productivity.

Generally, the respondents were optimistic about the potential positive effects of the technology particularly on improving soil, water, air, and health, among others. Respondents recognized the technology as an affordable, fast, and effective measure in restoring an exploited area; hence, they were inclined to adopt this in restoring the other mined-out areas in the municipality. In line with this, immediately after the Technology Forum last May 2018, the Office of the Municipal Environment and Natural Resources of Mogpog, Marinduque already signified interest in the technology and discussed with the implementers its potential application in the Municipality's Material Recovery Facility area. The area has been used as a dumping site for backfill materials from the mining operations. Immediate ocular inspection of the site was carried out together with the project implementers.

To complete the rehabilitation of the 32-ha mined-out area, the bioremediation technology should be adopted and implemented by the local government. Rehabilitation/reforestation efforts should use indigenous and endemic planting materials. This should also be applied in degraded and geologically hazardous areas including riverbanks and lakeshores.

Edible plants in the mined-out area may be planted only until thorough tests are done to confirm safety. Plants may uptake some contaminants which, as explained by *Vidali* (*2001*), may not be susceptible to rapid and complete degradation. *Rayu et al.* (*2012*) also discussed the constraints of phytoremediation and among these is the potential for contaminants to enter the food chain when people or animals consume the plants that have accumulated pollutants.

Similarly, water quality of water bodies near the mined-out area should also be assessed to ensure the safety of the community. This is recommended because of the presence of a lake, which developed from an open pit as a result of the mining activity. This lake became a source of water for irrigation and a habitat for fish utilized for domestic consumption.

The proven bioremediation technology may be applied in other mined-out areas, however, social acceptability assessment should also be undertaken. In decision-making processes, the needs, concerns and values of the community and other stakeholders should be taken into consideration. Their active participation in any development project, including those that concern sustainable rehabilitation activities, is encouraged in all stages of the project operations, such as in pre-implementation phase, construction/establishment phase, and monitoring phase. This is important to ensure commitment and project sustainability.

To strengthen the rehabilitation efforts, information and education campaigns should be regularly disseminated to inform the community, government, private companies, and all other stakeholders about the significance and values of sustainable conservation of natural resources.

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