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Riparian Vegetation Assessment for Effective Management of Molawin River, Mt. Makiling, Philippines

ABSTRACT

Molawin River is experiencing water quality degradation over time. Efforts were made to help rehabilitate this river to maintain its ecology and biodiversity. The main objectives of this research are: to identify and document water filtering plants (riparian flora) both present in terrestrial and aquatic ecosystems in the Molawin River and to pinpoint the sources and community perception that defies the idea of riparian flora species as potential water filtering plants in the Molawin River. Documentation of dense riparian flora present in the Molawin River was conducted in order to study its phytoremediation potential for water purification. A total of 107 morpho-species belonging to 94 genera from 56 families was recorded. The most common flora species was Commelina diffusa, Cyperus flabelliformis and Costus speciosus. A household survey and key informant interview were employed. The idea of riparian flora as a potential water purifying plants is facing four main challenges. First, there is a low conservation interest with the water resource, as this is not the primary source of water for them. Secondly, the presence of anthropogenic factors severely affecting the area. Thirdly, the high rate of encroachment of the invasive plants aggravates the conditions of the river. Finally, the lack of institutional support that can integrate riparian flora species in watershed management and rehabilitation planning.

Keywords: *riparian flora species, water filtering plant, Molawin River, institution, community perceptions*

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INTRODUCTION

Riparian zones and its water body contamination has grown to be a serious global concern. Freshwater ecosystems are under a great deal of stress and are being severely depleted as a result of pollution inputs. Chemical fertilizers, industrial waste, sewage, heavy metals from anthropogenic activities, and agricultural fertilizers can all contaminate water (*Pivetz 2001*). These pollutants, which are dumped into rivers and streams, can have serious negative effects on human health and the ecosystem. However, in order to effectively use vegetation to protect and improve water quality, land and water resource managers must have a thorough grasp of the various ways that riparian vegetation can impact water chemistry (*Dosskey 2009*).

Globally, according to *Clericia et al.* (*2014*) and *Wantzen et al.* (*2013*), riparian zones are being harmed by impermissible land use practices such livestock grazing, agriculture, urbanization, alien plant invasions, and higher pollution levels in catchments. In the Philippines, there had been substantial accounts of river and lake pollution because of urbanization (*Bautista 2013*). Among these water bodies is the Molawin River in Mount Makiling Forest Reserve (MMFR) (*LLDA 2015; Galang 2019*). Several studies showed that Molawin River has an increasing level of pollutants (*Briones et al. 2016; LLDA 2015; Bautista 2013; Paller et al. 2011*). Among others, agricultural and municipal wastes have contaminated Molawin river with heavy metals.

Freshwater ecosystems are of great importance for human life and human well-being. Nowadays, there is great interest in using plants as water purifiers in aquatic ecosystems. As what has *Schachtschneider et al.* (*2017*) had emphasized, riparian flora species are known to possessed characteristics of phytoremediation which can be utilized for ecological rehabilitation. The capacity of riparian flora species to ameliorate and remediate certain kinds of pollutants, through either phytoextraction or phytoremediation can be used advantageously in river pollution control and rehabilitation efforts (*Schachtschneider et al 2017*).

A lot of studies have shown that macrophytes can help in improving water quality through their contaminant uptakes. In this study, not only the macrophytes were studied, consideration of the riparian flora and vegetation was investigated. In this manner, pollutants not only in the water but also on the soil surface surrounding the water ecosystem can be covered. It generally aims to assess the diversity and composition of riparian flora and vegetation naturally present in both terrestrial and aquatic sections in the stretch of Molawin River and to document these riparian plant species as phytoremediators as part of natural river protection and management. Specifically, the study aims to (i) identify the riparian flora species that have water purification potentials, endemic and native in the Molawin River; (ii) analyze the perception of the locals of Brgy. San Antonio towards the use of these riparian flora species in managing Molawin River; and (iii) recommend institutional strategies that can promote the riparian flora species for water-filtering plants, a tool for the improving water quality of a surface water like the Molawin River. Additionally, this study will also explain the link between people's awareness and personal experiences in the development of riparian flora species in a protected area setting.

MATERIALS AND METHODS

Site Description

The study was conducted in the downstream section in one of the major tributaries of Mount Makiling Forest Reserve (MMFR), Los Baños, Laguna. Geographically, the study area is situated within 14°6' to 14°11' north latitude and 121°09' to 121°15' east longitude. The study area is part of the Molawin-Dampalit watershed and considered as the largest tributary MMFR. The Molawin-Dampalit watershed is one of MMFR's major drainage systems in terms of size and importance to lowland communities. It also has the highest density of creeks and rivers due to its many perennial streams as well as many smaller and intermittent streams.

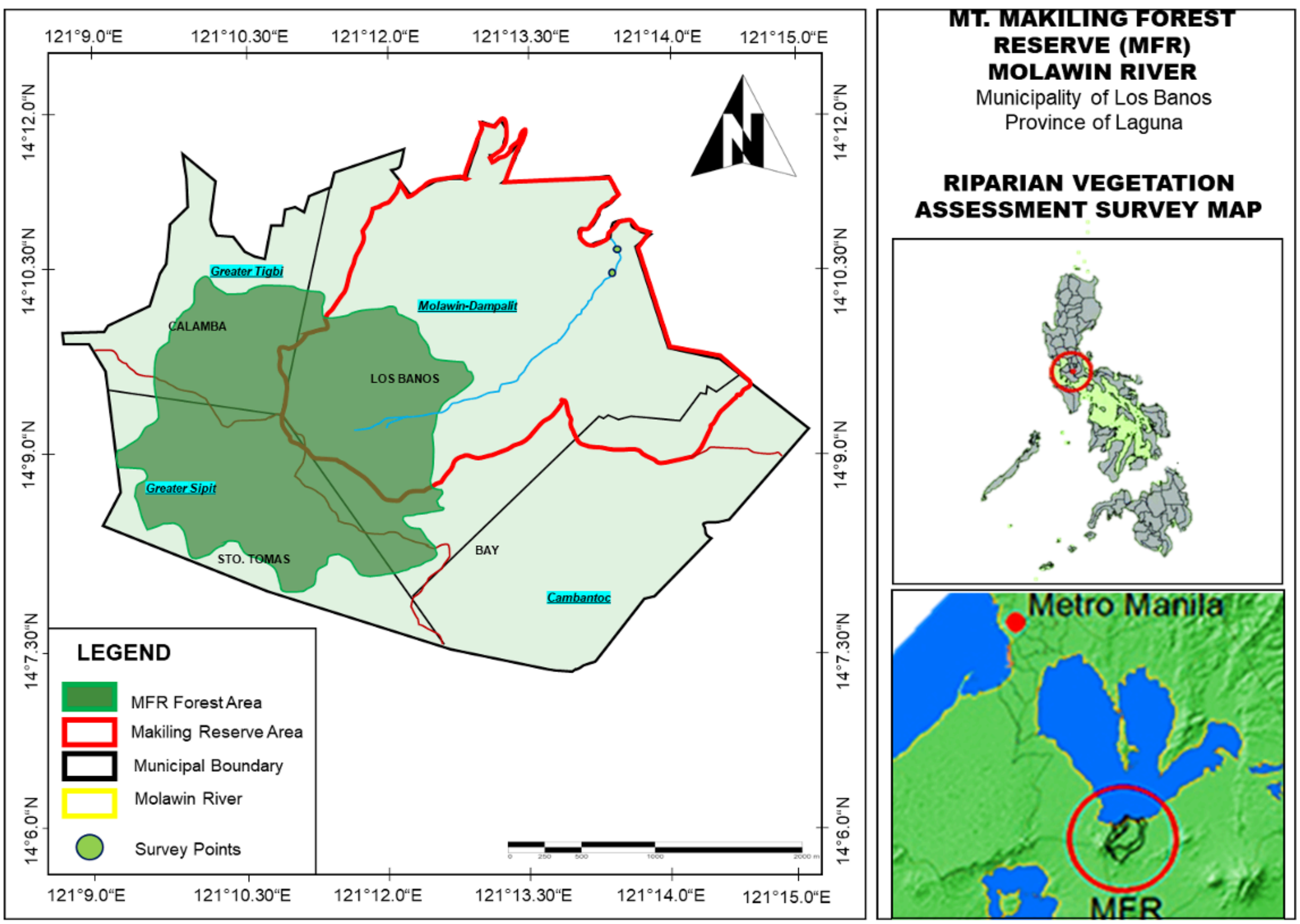

Figure 1. Map of the study area showing the sampling sites established in the Molawin River, Philippines

The survey was conducted during the wet season last October 13, 2019. The survey points were in the western portion of the UP Los Baños campus traversing 2-km up to the outlet point in Brgy. San Antonio, Los Baños, Laguna (**Figure 1**). It also forms the highest density due to its many perennial streams as well as the riparian section covered with dense plant species.

Documentation of Riparian Flora Species

A systematic flora survey was done to document the diversity and composition of riparian flora in Molawin River. The survey team used a modified belt transect method that was laid out along a 2-km transect with quadrats positioned at every 250-meter (m) interval. The transect line was placed 5-meters from the river line of which the reach of inundation levels during rains and high-water load occur. Along the transect was subplots or nested quadrats. This sampling technique was used to assess and to characterize the richness and species composition of the riparian vegetation. Photos of each species were taken to characterize them as digital herbaria of phytoremediation flora in the area. Identification of species was done and verified by the licensed forester who is also part of the research team. Secondary data gathering and review of available literature was done to support the assessment of Riparian Flora Species in the area with regards to their ecology and remediation potentials. Existing available literatures that were gathered and reviewed are only limited to determining species' phytoremediation abilities and did not further identify their biochemical composition.

Perception Survey and Key Informant Interview

An analysis was done to account the social perception relative to their awareness of riparian flora as potential water filtering plants and the perceived benefits of ecosystem services of Molawin River. The researchers conducted house-to-house surveys participated by residents inhabiting the riverside of the Molawin River. A total of 30 household respondents were interviewed in the area. Respondents were selected based on the number of households that were living near the river and their proximity to riparian vegetation communities. Key informant interviews (KII) were also conducted to gain information as to the management intervention being implemented in the study area. Moreover, data gathering answered questions regarding their socio-demographic profile (e.g., information of the users or sectors benefiting on water filtering plants), knowledge and perception about water-filtering plants (e.g., understanding riparian flora species and its values), ethnobotanical uses (e.g., folkloric medicinal plants) and institutional implications of such plants to the management of the river.

Factors such as knowledge and perception on the use of water filtering plants in the riparian section and the ecology of the river, as well as their sociodemographic characteristics are considered critical to sustainability of ecosystems such as the Molawin River. The integration of these factors is crucial to policy recommendations and institutional intervention (e.g., creating barangay ordinances). As what *Reyers et al.* (*2013*) emphasized, people's knowledge, attitude and practices affect ecosystem services in all aspects such as long-term benefits based on sustainable utilization and conservation. On the other hand, assessing the aforementioned factors to conserve ecosystem services offers all needed information on the value (e.g., ecological, social and environmental) of ecosystem services ranging from water resources, raw materials, food and all other environmental services that would serve as a basis for alternative uses, sustainable management of the community as well as aid in decision making (*Reyers et al. 2013*). All these if considered point to merit sustainable use would be needed in the brink of future environmental change, thus, providing an assessment about the outcomes of any environmental participatory projects of the government towards water conservation (*de Groot 2006*). Using the information concerning the institutional aspects, considerations, and problems in Molawin River, results of the perception survey and key informant interviews were used as vital foundation in formulating recommendations for institutional strategies that can promote this potential phytoremediation species as water-filtering plants as a tool for improving water quality in the Molawin River. The substantial points of the survey were analyzed based on the framework explaining indicators needed to be considered for the riparian flora species for the community to adopt them as water purifying plants.

RESULTS AND DISCUSSIONS

Documentation of the Riparian Flora Species, as Water Filtering Plants in the Molawin River

Based on the results of the plant survey, 107 morpho-species, with 94 genera belonging to 56 families, were documented in the area. It should be noted that fifty percent (50%) of the total plants surveyed were annual perennial flora, with rapid growth rate, high biomass, extensive root system, and ability to tolerate high amounts of heavy metals indicative of being an ideal plant for phytoremediation (*Tong et al. 2004*). Surrounding the river line, diverse species of trees and dense cover of bamboo poles were observed. These species include Tangisang bayawak (*Ficus variegata*), Tibig (*Ficus nota*) and an endemic species of Moraceae, Anubing (*Artocarpus ovatus*) and Kawayan killing (*Bambusa vulgaris*). From Transect 1, different macrophytic species were observed forming dense stands and as a sparse individual such as Johnson grass (*Sorghum halepense*), Gatilang (*Commelina diffusa*), Aurora (*Ipomea triloba*), Bonga-Bonga (*Alternanthera sessilis*) including some broadleaves macrophytic species such as Tuhod manok (*Ageratum conyzoides*), Uuko (*Mikania cordata*), Palong manok (*Celosia argentea*) and Palay maya (*Leptochloa chinensis*) (**Figure 2**). For the water filtering plants in Transect 2, different species of herbaceous plants thrive on the edge of Molawin River (**Figure 3**).

The documentation of riparian flora diversity conforms to the study of *Batty et al.* (*2000*), *Deng et al.* (*2004*) and *Schachtschneider et al.* (*2017*) in which an investigation on the dominance and abundance of riparian floras were undertaken. The study also confirms the account of *Mahbubeh and Bahare* (*2012*) that some grasses and weeds have high biomass and dense roots which could be used for phytoextraction. The case of the Molawin River shows a high density on the downstream section. On the other hand, invasive plant species in water bodies with disturbed and undisturbed vegetation was also assessed. Most of the plant species forms are herbaceous, woody perennials, and some are grasses of high biomass and shallow rooting (*Fitamo and Leta 2010; Napaldet et al. 2019*). Dominant families of riparian flora species were represented by Poaceae, Commelinaceae, Rubiaceae and Asteraceae. Abundance of riparian flora species is higher in downstream section (T2) with 61 species. This is primarily due to the vegetation condition of the area in which canopy trees are minimal and the width of the river affects water flow. Hence, this is more conducive for growth and development of riparian flora species. The abundance of flora in T2 may be attributed to the condition of the area wherein the water body is exposed to anthropogenic factors (e.g. settlements, built-up areas, roads) in which proliferation of metal absorbing riparian flora species became much more diverse.

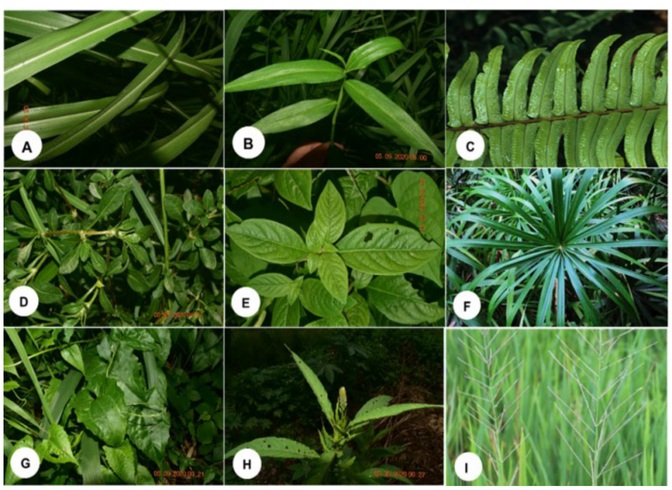

Figure 2. Documented riparian flora species in the Molawin River in transect point 1. (A) Johnson grass (*Sorghum halepense*) POACEAE; (B) Gatilang (*Commelina diffusa*); (C) Pakong kalabaw (*Nephrolepis biserrata*); (D) Bonga-Bonga (*Alternanthera sessilis*) RUBIACEAE; (E) Broadleaves macrophytes; (F) Tuhod manok (*Ageratum conyzoides*); (G) Uuko (*Mikania cordata*); (H) Palong manok (*Celosia argentea*); (I) Palay maya (*Leptochloa chinensis*)

Originally, water hyacinth (*Eichornia crassipes*) is known for remediation abilities (*Akinbile and Yusoff 2012; Lituanas and Cadiz 2018*). This was the main component of phytoremediation in the Molawin River (*Zafaralla 2010*). However, the emergence of other different flora species indicates high levels of metalloids in the water body as demonstrated bv *Lituanas and Cadiz* (*2018*) in their studies of riparian phytoremediators. However, the emergence of other different flora species indicates high levels of metalloids in the water body as demonstrated bv *Lituanas and Cadiz* (*2018*) in their studies of riparian phytoremediators. Species of Kahoy-Kahoy (*Ludwigia octovalvis*), Alikbangon (*Commelina benghalensis*),

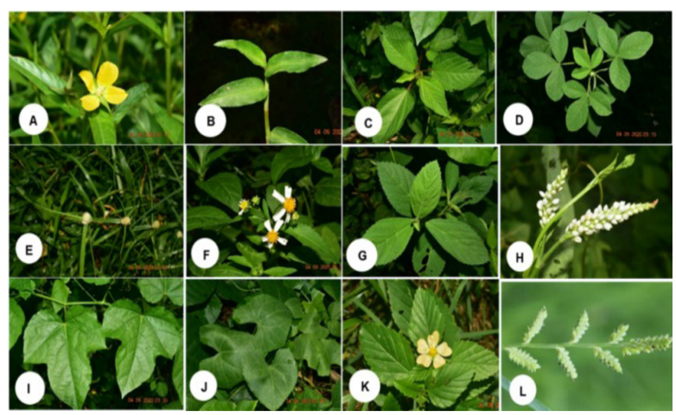

Figure 3. Documented riparian flora Species in the Molawin River in transect poist 2. (A) Kahoy-Kahoy (*Ludwigia octovalvis*); (B) Alikbangon (*Commelina benghalensis*); (C) Malasaluyot (*Corchorus aestuans*); (D) Palpatog (*Crotalaria retusa*); (E) Mutha (*Cyperus rotundus*); (G) Takling baka (*Sida rhombifolia*); (H) Burat-aso (*Sphenoclea zeylanica*); (I) Karunggut (*Passiflora foetida*); (J) Melon daga (*Zehrenia indica*); (K) Walis-walisan (*Sida acuta*); (L) Pulang pwet (*Echinochloa colona*)

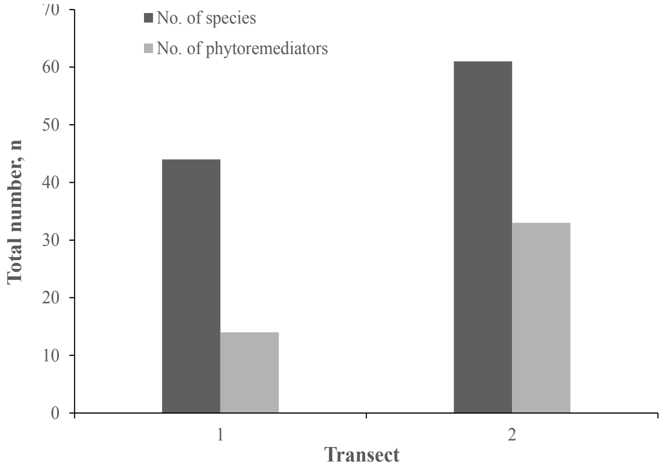

Figure 4. Abundance of riparian flora species in Molawin River

Malasaluyot (*Corchorus aestuans*), Palpatog (*Crotalaria retusa*) and Mutha (*Cyperus rotundus*) are among the macrophytic plant species that were observed in T2 (**Figure 4**). These species were evaluated for their comparative potential to phytoremediate cadmium (Cd) and other basic metalloids from soil (*Zulfiqar et al. 2012*). On the other hand, *Wang et al.* (*2008*) did a phytoremediation study of similar species such as plant species belonging to *Cyperus* sp., *Ipomoea* sp., and *Passiflora* sp.

Looking at the findings of *Pinzón et al.* (*2010*) and *Sekabira et al.* (*2011*), they also reported that Alikbangon (*Commelina diffusa*) accumulated toxic metals such as Cr, Cd, Pb and As, both at the root and at the shoot in high degrees. Comparatively, it is present in the Molawin Alikbangon (*Commelina diffusa*) is present in Molawin River, particularly near roads going to the railroad section. *Pinzón et al.* (*2010*) and *Sekabira et al.* (*2011*) reported that Alikbangon (Commelina diffusa) accumulated toxic metals such as Cr, Cd, Pb and As, both at the root and at the shoot in high degrees. *Sekabira et al.* (*2011*) presented that riparian ecosystems tend to have denser coverage of flora individuals, since most of the growth and development resources such as moisture are abundant. The study documented at least 40% of weedy taxa species in Molawin River. These were used in phytoremediation studies of *Gupta and Sinha* (*2008*), *Madurapperuma et al.* (*2013*), *Babu et al.* (*2017*) and *Suresh et al.* (*2020*) such as: Tuhod manok (*Ageratum conyzoides*), Uuko (*Mikania cordata*), Palong manok (*Celosia argentea*) and Palay maya (*Leptochloa chinensis*) for filtering and cleaning-up As-contaminated surface water and wetland areas *(Mahmud et al.,* *2008*); *Alternanthera sessilis, Xanthosoma violaceum, Commelina benghalenis, Cynodon dactylon* for Cd, Pb and Zn (*Liu et al. 2007*); *Monochoria vaginalis* for Cd

Table 1. Screening criteria for chronic toxicity data of different taxonomic groups.

Parameters	Transect 1	Transect 2
No. of Species (n)	44	63
Total number of Genera	36	58
No. of Families (F)	21	35
Total number of Phytoremediators	25	39
Total Number of Plots	4	4
Total Number of Species (N)	107	
Total Number of Common Species in the transect	75	
Species Difference	32	

and Pb, *Sida rhomboidifolia* for Co, Ni, and Pb, and Cyperus flabelliformis and *Fimbristylis miliacea* for Zn (Liu et al. 2007). Moreover, *Hammami et al.* (*2016*) and *Damilola and Morenikeji* (*2013*) reported that Tridax procumbens and Solanum nigrum are effective species as phytoremediator of Cd-contaminated soil while *Eddy and Ekop* (*2007*) reported that *Chromolaena odorata* and *Stachytarpheta jamaicensis* can absorb Pb, Zn, Cd, Cu and Ni from contaminated soil and riparian systems.

Challenges in Recognizing riparian flora species as Water Filtering Plants

Perception of households on riparian flora species as water filtering plants. The study revealed high ethnobotanical knowledge and familiarity of the interviewed respondents in terms of water purifying plants in the area. This is a result of their knowledge gained from the previous Aquatic Macrophyte Bioabsorption System (AMBS) study of the University of the Philippines Los Baños (UPLB). The folklore information also helped in having ethnobotanical good knowledge. Informants identified 47 medicinal and edible plants. These were also identified by the study as phytoremediation plants supported by various literature and phytoextraction studies. When respondents were asked about their knowledge and personal experience on phytoremediation plants species present on Molawin River, the most often identified project was the AMBS. *Zafaralla* (*2016*) in their AMBS project, emphasizes effective strategies that can transform degraded and polluted streams and shallow rivers into productive fish habitats. The process would develop a mat of roots that filters the solids as well as absorbs and adsorbs the pollutants, including the heavy metal pollutions dissolved in the water, with the presence of water filtering plants that are capable of absorbing heavy metals in water, known ecologically as phytoremediators (*Verla et al. 2018*). The result is clearer and cleaner water that is conducive to fish habitation. With this, fish diversity has been restored and transformed

Molawin River becoming again breeding ground of various fish species. This brought participation and positive community perceptions towards the protection of Molawin River and its ecology. Their perception and awareness (including personal knowledge) deepened based on the level of involvement in the previous intervention studies. From this, it is found out that resident participation and commitment are key factors in developing effective river ecology policies towards Molawin River with the help of institutional sectors.

As per the personal knowledge on water purifying plants, most residents stated that they are familiar with these, and they personally encountered these plants. Some of the respondents also identified these as water purifying plants as well as being medicinal plants too. Other residents categorized them as a typical part of vegetation such as trees, edible plants, and weeds in the area. In fact, 50% (15) of the total interviewed residents responded that they have experienced utilizing this plant species for planting in your backyard or garden ornaments On the other hand, 40% of the total respondents expressed that they are not aware that some of the plants they are using are water purifying plants while 43% of the total interviewed residents know the plants more as either medicinal or edible plants due to their frequent use (N=13). Lastly, 20% of the total interviewed residents had no idea about water filtering plants and its use or value. However, 100% of the total interviewed residents viewed the presence of riparian flora species in their surroundings as beneficial to rehabilitate the present conditions of Molawin River in terms of water quality.

The main ecological function of riparian flora vegetation, according to *Yusuf et al.* (*2019*) is mostly for weakly contaminated soils and waters. This is commonly applicable when the material to be treated is at a shallow or medium depth and the area is large. *Diah et al.* (*2014*) illustrated that this will make the ecology of the area better in terms of indigeneity and ecological health. In addition, the area partners– which is the community– must be prepared to accept a longer remediation period (*Araral 2009*). *Pandey and Singh* (*2017*) elaborated that plants that can decontaminate soils through one or more of the following: plant uptake of contaminant from soil particles or soil liquid into their roots; bind the contaminant into their root tissue, physically or chemically; and transport the contaminant from their roots into growing shoots and prevent or inhibit the contaminant from leaching out of the soil. Molawin River has a dense vegetation of Paper mulberry (*B. papyrifera*) (**Figure 5**).

The potential use of riparian flora species for phytoremediation, in general, is inherent to the plant species characteristics since most of its needed micronutrients were abundant in the river, however, some factors would affect its general growth and development *Sholeh* (*2016*) in their study of phytoremediators elaborated that, several factors can affect the absorption capacity of heavy metals by plants, namely plant species, the nature of the substrate used, root distribution, and vegetative uptake. *Bech et al.* (*2002*) identified factors such as: production of enough biomass and plant being responsive having the shoots as an important part for accumulation. Common pollutant accumulating plants found by phytoremediation researchers present in the Molawin River (**Table 2**).

Figure 5. Photo documentation of Molawin River with riparian flora vegetation. (A) Dense vegetation of Paper mulberry (*B. papyrifera*) and (B) Molawin creek that runs perpendicular to the existing railway track. Sheltering some native species of trees such as *A. ovatus, T.orientalis, F. variegata and P. indicus*. Riparian flora form in the creek are grasses, herbs and sedges such as Umbrella grass (*Cyperus flabelliformis* Rottb.)

Table 2. Plant species growing on Molawin River, Mt. Makiling, Philippines that are highly potential for phyto-stabilization, phytoextraction, and phytodegradation.

Species	Metal elements absorbed (Riverine metalloids)	Reference
Ricinus communis L.	Cd, Cu, Ni, Pb, Zn	*Kiran and Prasad 2017*
Commelina diffusa L.	Cu, Cr, Ni, Pb	*Bwapwa et al. 2017; Garcia et al. 2019 Babu et al. 2017;*
Sida rombhoidifolia L.	Co, Ni, Pb	*Chu et al.2019; Suresh et al. 2020*
Adiantum caudatum L.	Pb, Ni and Co	*Praveen and Pandey 2020*
Pteris ensiformis Burm.	Pb, Ni and Co	*Pongthornpruek et al. 2008*
Adiantum philippense L.	Pb, Ni and Co	*Prabhu et al. 2016*
Solanum nigrum	Cd	*Hammami et al. 2016*
Xanthosoma violaceum	As, Pb, and Hg	*Tangahu et al. 2011*
Commelina benghalenis L.	Pb, Cd, Cu and Zn	*Casila et al. 2019*
Cynodon dactylon L.	Pb, Cd, Cu and Zn Fe, Mn, Ni	*Kumar et al. 2019; Ancheta et al. 2020;*
Murdania nudiflora (L.) Brenan	Basic metals on soil	*Hasan et al. 2017*
Pollia secundiflora (Blume) Bakh.f.	Basic metals on soil	*Pandrey 2020*
Tradescantia spathacea Swartz	Basic metals on soil	*Priya and Selvan 2017*
Ludwigia octovalvis (Jacq.)	Zn, Cd, Ni, and Pb	*Idris et al. 2016*
Cyperus flabelliformis Rottb.	Zn, Cd, Ni, and Pb	*Garba et al. 2015*
Cyperus kyllingia Endl.	Zn, Cd, Ni, and Pb	*Garba et al. 2015*
Cyperus rotundus L.	Zn, Cd, Ni and Pb	*Ogbonna et al. 2016*
Scleria scrobiculata Nees.	As, Pb, and Hg	*Dickinson, 2017*
Urena lobata L.	Cu, Zn and Fe	*Idris et al. 2016*
Canna glauca L.	Cd and Zn	*Subhashini and Swamy 2014*
Costus speciosus (Koenig) Smith	As, Pb, and Hg	*Anyanwu et al. 2020*
Alpinia elegans (Presl.) K. Schum.	Fe, Zn and Si	*Vartika et al. 2001*
Curcuma longa L.	Basic metals on soil	*Rai et al.2001*
Globba campsophylla K.Schum.	Basic metals on soil	*Szoszkiewicz et al. 2007*
Echinochloa colona (L.) Link.	Ca and Si	*Idris et al. 2016; Pierantoni 2012*
Chloris barbata (L.) Sw	Ca and Si	*Pulcherie et al 2018*
Nephrolepis biserrata (Sw.) Schott	Cu and Au	*Ancheta et al. 2020*
Pityrogramma calomelanos (L.) Link	Cu and Au	*Ancheta et al. 2020*
Christella dentata	Zn, Cd, Ni, and Pb	*Yee 2014*
Costus sp.	Zn, Cd, Ni, and Pb	*Umukpong and Edward 2018; Petelka et al. 2019; Anyanwu et al. 2020*
Piper umbellatum L.	Zn, Cd, Ni, and Pb Zinc (Zn), Cadmium	*Ndjonka et al. 2018*
Ficus nota (Blanco) Merr.	(Cd), Nickel (Ni) and Lead (Pb)	*Navarrete et al. 2017*
Sphenoclea zeylanica	Cd	*Borines, 2019*
Stachytarpheta jamaicensis	Pb, Zn, Cd, Cu and Ni	*Eddy and Ekop 2007*
Ficus benjamina L.	Cd and Zn	*Guzman-Morales et al. 2018*
Musa acuminata Colla	Cd	*Mohd et al. 2015*
Chromolaena odorata	Pb, Zn, Cd, Cu and Ni	*Eddy and Ekop 2007*
Alocasia portei Schott	Ni	*Mohamad et al. 2020*
Syngonium podophyllum Schott	Cd and Zn	*Liu et al. 2017*
Flagellaria indica L.	As, Pb, and Hg	*Gnanaraj et al. 2015*
Tridax procumbens	Cr, Cd, Pb, NI	*Hammami et al. 2016*
Alternanthera sessilis	Ni, Cd, Cr, Pb and Cu	*Kananke et al. 2016*
Fimbristylis miliacea	Basic metals on soil	*Liu et al. 2007*
Crotalaria retusa	Ca and Si	*Haroni et al. 2019*
Corchorus aestuans	As, Pb, and Hg	*Ameh et al. 2019*
Monochoria vaginalis	Cd, Pb, and Hg	*Liu et al. 2007*
Zehrenia indica	Cu, Zn and Fe	*Nguemte et al. 2018*

The initial results of the survey on riparian floras and their filtering potential were also presented in the community by showing actual photos of available riparian flora species in the area. This was done through impromptu communications with residents living near Molawin River and providing them actual samples of species specimens during the survey.

Anthropogenic factors: **livestock, clearing forests for settlement and agriculture**.The vegetation of the area is severely affected by occasional dumping of some residual waste (e.g. diapers, napkins), clearing of vegetation and livestock (e.g. piggery). Additionally, there were natural disasters resulting to flooding and occurrences of riverbank erosion near the area. These covered some parts of the Molawin River making some residences not too familiar with some other water purifying plants in the river. Furthermore, since the area is near to a railway track, vegetation is kept at maintained growth such as grasses and shrubs. With this, diversity of riparian flora in the area decreased. Other environmental constraints that hinder the natural growth of these plants are human induced including soil disturbances and destruction of river ecology. Moreover, as a point of observation, the "weedy" taxa became dominant in the area. Pollution of the river in terms of leachates from agricultural activities is unceasing with no monitoring system and pollution abatement technologies. Hence, Molawin River's water quality continuously degrades. *WWF* (*2020*) accounted that many of the water systems that sustain ecosystems and human population have become stressed such as rivers, lakes and aquifers in terms of ecological health.

Presence of invasive encroaching plants. Molawin River contains enormous plant remediators and the diversity of it is considerable. In terms of indigeneity of the area, some of the herbaceous plants, sedges and grass species are declining such as Zingibers, Cypers and Bamboos. This is possibly due to disturbance such as natural disasters causing widening of canopy gaps. This eventually made light penetration of the ground, drying the soil. Zingibers and other proto-terrestrials are known to be shade tolerant species (*Fernando et al. 2013*). There is also a significant presence of invasive encroaching plants such as Broussonetia and Chromolaena species and Dagad (*Tridax procumbens*). Molawin River contains enormous plant remediators and the diversity of it is considerable. As a strategy to conserve these plant species, the area can be installed with small engineering structures such as ripraps and caged plants to further filter pollutants and harbor biodiversity. It would also take away invasive plants that may be considered a nuisance There were documented invasive plant species that dominates portion of open areas in the Molawin River (**Figure 6**).

Institutional support, recognizing acrophytes as natural water quality enhancer. Twenty-two (22) respondents are aware of the poor conditions of the Molawin River (**Figure 7**). This is despite the efforts of some formalized institutions such as academic institutions to rehabilitate the river to accrue many ecological benefits for the community. For the respondents, Molawin River is not the primary source of water. And due to its degrading water quality, this river ecosystem services being offered are less, hence giving less value to them. The impacts from the degradation of water quality in the area are really felt downstream.

Water treatment procedures can aid in enhancing the Molawin River's water quality. Costs are involved in treating water pollution. According to *Adler et al.* (*2000*), there must be a valuable naturally occurring substance that can be used to treat water less expensively, similar to ecologically constructed systems (*Umukpong and Edward 2018*). However, not much institutional policies and programs are focused in promoting phytoremediation in the Philippines to improve water quality. Moreover, the only law attributed to good water quality are policies which focused on solid waste management (Republic Act 9003 or the Ecological Solid Waste Management Act), disposal of hazardous and toxic substances in bodies of water (Republic Act 6969 or the Toxic Substances and Hazardous and Nuclear Wastes Control Act), and the well-known Republic Act 9275 or the Philippine Clean Water Act which is generally focused on industry and engineer-based technologies to improve water quality such as putting up wastewater treatment facilities, septic tanks, among others.

Environmental implications. Water bodies such as lakes and rivers play key important roles in maintaining biodiversity, ecology and sustenance to human life. As part of the key environmental services that rivers provide, water is among the key ecosystem services that sustain life cycles for all organisms including humans. As what as *Luqman et al.* (*2013*) had emphasized, supporting services of riparian ecosystems benefits more functions related to hydrology and sediment. Dynamics include storage of surface water and sediment, which reduces damage from floods downstream from the riparian area. However, it is also vulnerable to many disturbances. Reverse impacts become more rampant for many water bodies such as being a waste reservoir and being prone to proliferation of invasive encroaching plant species losing their indigeneity.

Maintaining biodiversity is one of the most important functions of riparian areas and is the basis for many valued fisheries, in addition to bird and other wildlife habitat. The benefits of functioning riparian areas to fish stem directly from the role of vegetation in controlling temperatures, stream structure, and sedimentation. Riparian areas

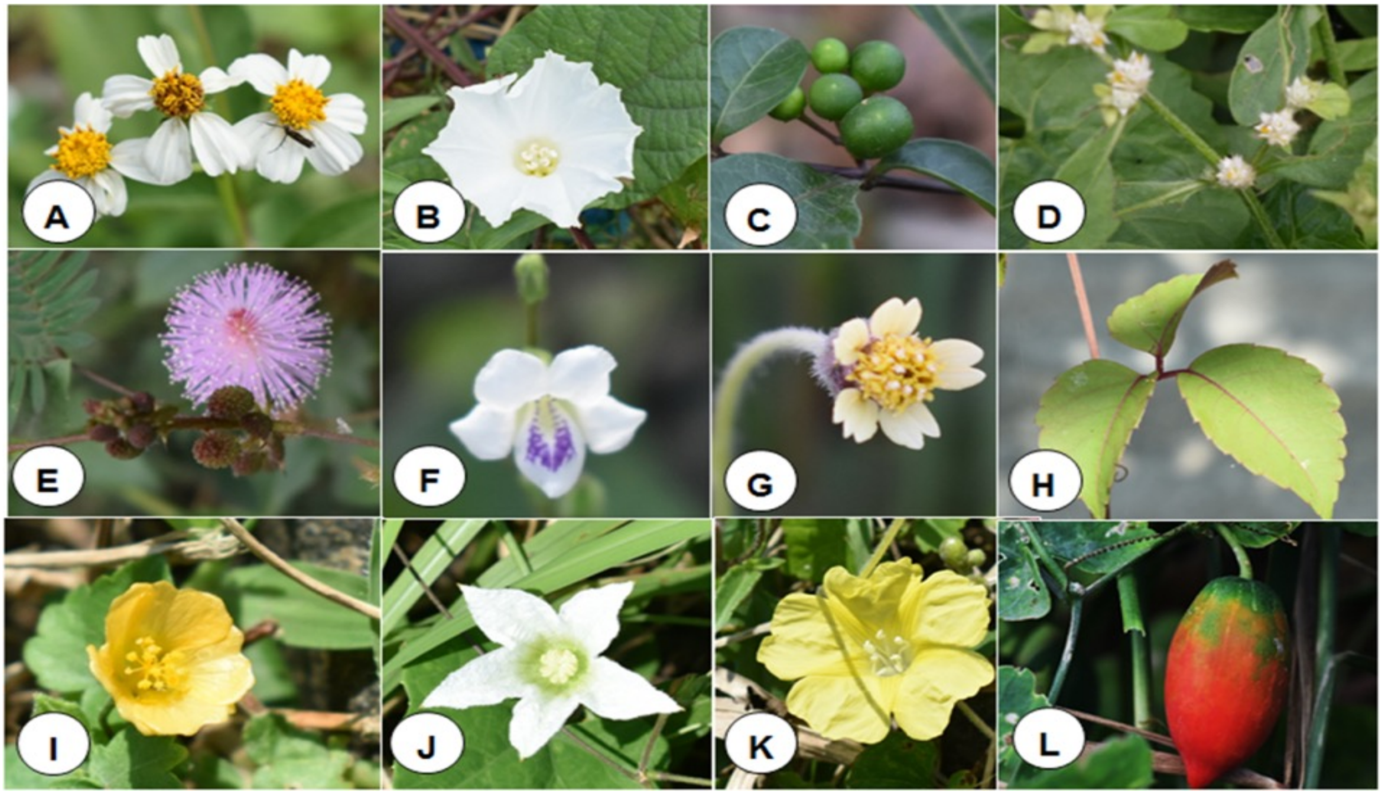

Figure 6. Some of the photographed and recorded dominant ground cover species at different sections near Molawin Creek. (A) Dadayem (*Bidens alba* (L.) DC.); (B) Aurorang gubat (*Ipomea triloba* L.); (C) Bagan-Bagan (*ycianthes biflora* (Lour.) Bitter); (D) Bunga-Bunga (*Alternanthera sessilis* (L.) R.Br. ex DC.; (E) Makahiya (**Mimosa pudica* L.); (F) *Asystasia gangetica*, (G) Dagad *(Tridax procumbens* Linn); (H) Alangingi (*Cayratia trifolia* (L.) Quis.); (I) Igat-Igat (*Sida javensis* Cav.); (J) Melon daga (*Zehneria indica* (Lour.) Keraudren); (K) Aurora (*Ipomea* sp.); (L) Tamling (*Coccinea grandis* (L.) Voigt).

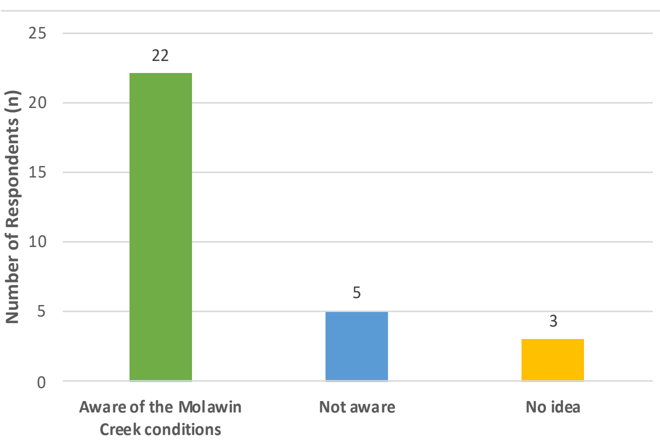

Figure 7. Number of household respondents and thei rperception of the ecological conditions of Molawin River, Mt. Makiling, Philippines

themselves are home to an abundance of animal life, including invertebrates, almost all amphibian species and many reptiles, the majority of bird species (particularly in southern areas of the country) and many mammals.

The state of the water resource can be described according to its use and physical condition. In this case, the hindrance of gathering individuals' interest in conserving water resources and protecting the water body will be difficult. Since the water body traversing the community is not actually part of their source of water, the likelihood of conserving it may be deemed optional for them. However, internalizing the different environmental services they can get from the water body would lift their interest and willingness to conserve the state of water resource of Molawin River (**Figure 8**).

The community having other sources of water sees Molawin River as not the most essential water source. This is as the households have a main water provider for potable water. Sixty percent (60%) of the respondents stated that the residents are the polluters of the Molawin River. Others identified companies and other nearby business operators. This is as the river became a direct waste reservoir including the dumping of residential and livestock waste. No wastewater treatment is present in the area. Despite the awareness of the pollution problem, only 17% agreed that the water quality is poor. Thirty-seven percent (37%) said that the water quality is not

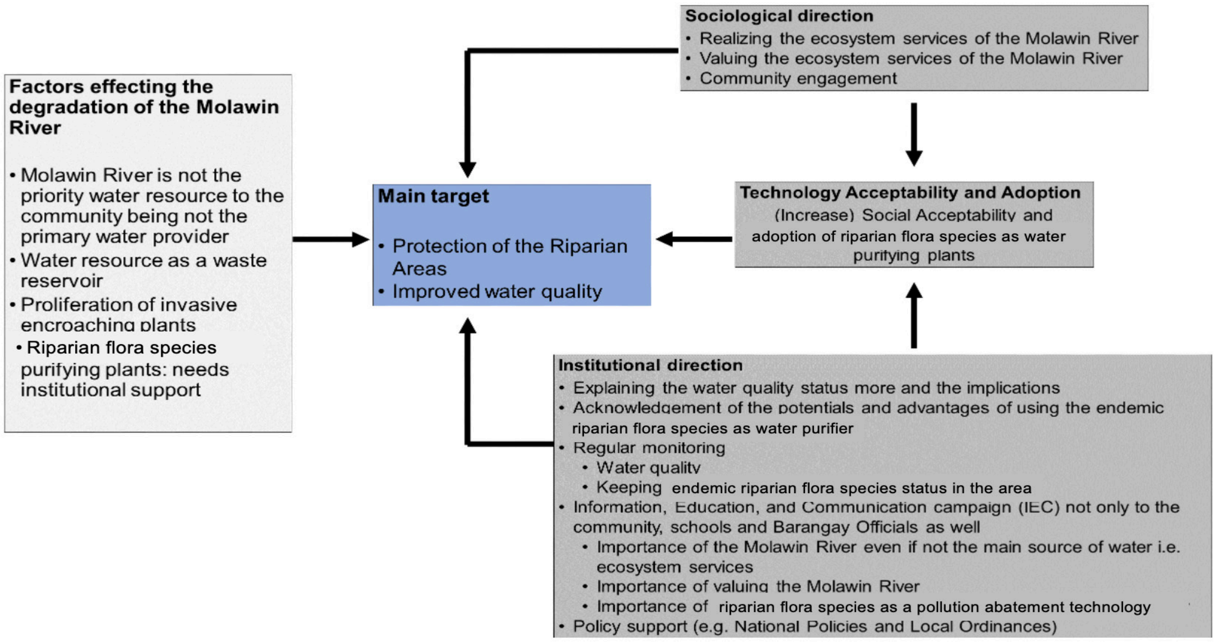

Figure 8. Framework explaining indicators needed to be considered for the riparian flora species for the community to adopt them as water purifying plants.

so bad and not so good. Forty-seven percent believe that the Molawin River is still beneficial to them. Notwithstanding the water problem, the residents think that the Molawin River serves as another water source for their activities, e.g., for agriculture activities.

Molawin River also has its charm that provides aesthetics to the place and attracts tourists. Unfortunately, 70% of the respondents argued that this river has no protection against further water quality degradation. There is also a proliferation of invasive encroaching plants. As for the riparian flora species documented as water purifiers, no existing ordinance or institutional element is present to support or encourage their presence. It is evident that the Molawin River needs enhancement as a water resource. The primary objective is to protect the riparian areas and to improve the water quality. In order to achieve this, the awareness of households can serve as an indicator that riparian flora species is a viable pollution abatement technology i.e. water purifying plant (**Figure 7**). flora species as a pollution abatement technology i.e. water purifying plants.

It is important that the community and the local government elevate the identification and appreciation of the ecosystem services (i.e. supporting, provisioning services, regulating and cultural services) of this river. Knowing and appreciating these can further augment the total economic value of the Molawin River. The increase in value can make the community engage more in the activities that can help in protecting and managing this important ecosystem more.

For the community to accept and appreciate the value of ecosystem services of Molawin River, their knowledge, sense of value, appreciation and their views of protecting the water body needs to be understood. Further, uplifting the value of the Molawin River needs harmonizing of different sociological and institutional perspectives (e.g. role on river protection, IEC etc.). With this integrative approach, the acceptability of community residents can easily be achieved. The recognition of their sense of the resources' use and non-use values should be analyzed in a manner that such environmental services (e.g. provisioning and supporting) will be identified as part of their everyday life and recognized what services are related to them. This outlines how the community appreciates water resources such as rivers. Eventually, this draws them towards water conservation. In this line, any potential technology that can enhance the water quality of the water system can be acceptable. The interconnection of each component in the framework further breakdowns the relationship of the water as ecosystem services being used: the user group's characteristics, the behavior/attitudes of the users and the direct drivers or threats that affects the likelihood of accruing benefits from Molawin River's water resources or likely to hinder people's participation, and willingness to conserve it.

In water management, it is important to bring the people closer to the water by looking deeper into the sociological aspect. *Buurman and Padawangi* (*2018*) suggested that this can be through making water as a place for social interactions, water as a medium for social awareness and influencing behavior, and water as an input to social cohesion. From another point of view, people's attitude and willingness are directly influenced by knowledge and practices towards water resource value. Every individual or household may value a resource in multiple ways, making different claims and attitudes about value of water in different social and ecological contexts (*Sen 2007*). Consequently, *Folke* (*2005*) emphasized the very nature of human-environment interaction by means of ecosystem services as what *Sen* (*2007*) already elaborated, that understanding this plurality of ways and means of valuing ecosystem services is a critical point in identifying suitable and sustainable ways to manage feedbacks, attitudes, behavior, willingness to participate and other key determinants of conservation attitude towards ecosystem services conservation (*Norgaard 2010*). Hence, well adaptive management of complex social-ecological systems is also essential.

In terms of technology acceptability and adoption, activities that can protect and manage the Molawin River better will entail pollution abatement technologies. The riparian flora species that proved their function in terms of purifying the water are already present in the area. This can provide a good opportunity to improve the water quality, naturally and readily available. Acceptability on the use of this technology and adoption can increase the capacity of the river to naturally cleanse its water.

Institutions have major roles in making people understand how to have more effective water use and governance (*Patterson and Beunen 2018*). Water resources managed by different sectors are more on regulating human actions towards natural resources (*Meyfroidt 2013*). Institutional efforts are important primary working factors and forces for water resources management. As what Ferragina (2002) emphasized, management of a resource typically involves policy development relative to the protection of water bodies,its primary services, and its environmental management. The protection and conservation of these natural resources is predominantly a government function (*Sen 2007*). However, this should not preclude private participation of NGOs and other groups related to water resources. Institutions are important in taking actions that can make the people engage in managing the river better and adopting the readily available technology. Although the community is aware of the degraded water quality, implications should be explained further, especially on how it can affect the community. The local government can help by promoting the river through its ecosystem services and how well it can be optimally used. As the river needs actions in order to improve the water quality, national and local institutions can aid in acknowledging the potential and advantages of using endemic riparian flora species as a water purifier.

Consistent and regular monitoring is still needed in terms of the water quality and making sure that the endemic riparian flora proliferate healthily in the river. Strengthening the Information, Education, and Communication (IEC) to the community, surrounding schools and Barangay Officials is an important movement. Wherein the importance and the value of the Molawin River will be emphasized. The essence of knowing and evaluating the potentials of riparian flora as phytoremediators that are helpful for elevating the water quality and how these can be managed and protected are needed. Implementation of the said activities in the area can be more effective if this policy is supported through national policies and local ordinances can be made.

CONCLUSIONS AND RECOMMENDATIONS

The ability to protect biological resources relies on the ability to identify solutions to ameliorate the effects of human activities on biological systems such as the ecology of Molawin River. The study documented diverse species of riparian flora with at least 107 plant species as phytoremediators in which 47% are phytoremediation plant species. Based on documented studies, it is found out that 55% of the identified potential phytoremediators possess characteristics for heavy metal extraction.

The existence of these plant species was critical to the present knowledge and awareness of household residents living adjacent to the river whose activities were focused relative to the deteriorating ecology of the water body. With the escalating threats that the river is facing, there is a need to assess and provide doable solutions to protect the ecological services it possesses such as water. Riparian flora species species that naturally thrive in the area form a protective barrier against pollutants that can significantly affect the ecological balance of Molawin River.

With the enormous riparian flora diversity existing in Molawin River for phytoremediation, special attention should be given to analyze environmental effects on riparian ecology and ecosystem services, which has been until now too often neglected. Accounting for combined environmental, social, and institutional interventions and factors will greatly enhance the River ecology and will solely reflect anthropogenic disturbance effects the Molawin River is facing. Moreover, the introduction of institutional initiatives serves as a baseline to answer and solve constraints that are brought about by implementation of policies concerning water quality improvement. In the long run, it is expected that institutions will create programs and schemes that shall introduce further phytoremediation through disseminating information about its uses, importance, cost efficiency, and ecological importance.

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