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Site Level Geospatial Analysis for Intensity Index of Gold and Copper Mining: Impact on Biodiversity and the Potential for Blockchain Integration

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Abstract

Large-scale and small-scale metal mining operations may not have been considered in the past as big threats to the observed local to global biodiversity pressure, but their zones of influences may adversely change species habitats, directly, indirectly, at local and regional scales. In this study, the intensity index on biodiversity is generated from mining gold and copper in Itogon and Tuba areas in the Philippines. These two areas are located in Northern Luzon with high base metal concentration in porphyry veins deposits with a host of biodiversity due to the distinct biogeographic, altitudinal gradient and climate. The endemic and threatened flora Nepenthes Bellii K. Kondo, Shorea polysperma, Pterocarpus indicus Willd and Lilium philippinense Baker within three mining sites indicated as X, Y, Z are used as species under threat and with multiple variable summation of their geospatial pattern of occurrences and by using by Python Programing Language to compute the Mining Factors (MF) from the Mines Annual Production and Percentage Grades, thereafter, the MF is multiply by the Biodiversity Factor (BDF) which is define as the product of the mines Area Factors (AF) and Protected Area Factor, and the values obtained are divided by Fibonacci Extinction Factor; which is the species Area of Occupancy(AOO) divided by the Extent of Occurrence(EOO) raised to the power of the corresponding Fibonacci Number. The final output is multiplied by the Potential Ecological Risk Indexes from the Heavy metals released from the mines. FEF is generated from QGIS geospatial analysis and the IUCN biodiversity Red List Category that finally yields the MintBio index. MintBio index values generated are subjected to linear regression analysis using Microsoft Excel data analysis tool to test the statistical significance. The MintBio indexes obtained are independent of mining scales or MF but depend heavily on the FEF and AF suggesting that MintBio as a model could serve as an attribution and intensity index to quantifying mining pressure on the ecosystem and species diversity that are often ignore using only biodiversity proxies such as trees cover and protected area. The value of the MintBio obtained in this study ranges from 686.756 of mine Z to 33,614,780.60 of mine Y indicating vast differences that were captured due to the higher threat of mine Y to the endemic and threatened species within 5km from the mine center. The inclusion of conservation factors to the index would further increase such sensitivity for a better evaluation and such would create the opportunity for incentives for mines operating responsibly and with high conservation tract records. MintBio is a potential model to improve policy targets in biodiversity monitoring, impact verification, corporate and environmental management in eco-designs, eco-labelling for huge metal consumption industries and would foster validation of sustainability claims regarding mining if integrated into blockchain as solution framework for proof-of-zero impact to biodiversity supply chain and international financing standardization for metals trade impact index options from mines in the Philippines and those across the globe.

Keywords: Biodiversity, mining pressure, Geospatial Analysis, Mining Intensity Index, Policy target, Blockchain

INTRODUCTION

A fundamental shift in genetic, species and ecosystem diversity has been observed and monitored by scientists across the globe and an important pattern is being reported- an on-going global environmental pressure on our biological diversity. However, large-scale metal mining operations may not have been considered in the past as a big threat to the observed trend, their zone of influence may adversely change habitats, directly, indirectly, at local and regional scales (Diego et al., 2016). Statistically, the above study concludes that overall, 23% of mines and 20% of ore deposits are located in areas of high plant diversity, 63%

of mines and 61% of deposits are found in areas of intermediate plant diversity, 13% of mines and 19% of deposits are located in areas of low plant diversity, and over 50% of deposits occur in diversity zones 1–4 covering 56% of the land surface. Monitoring this change is essential in order to identify the causes and to generate the variables that could be used to inform scientists, our leaders and the general public on global biodiversity changes (Proenca et al., 2016).

Uncontrolled metals presence in the environment have been reported by many researchers and ecotoxicologists to have potentials of bioaccumulation due to their non-biodegradable characteristics and as such could be biomagnified in species resulting in several degree of toxicity of the enzymes of biological organisms. Among these metals, heavy metals residues of mines are distributed in the various ecosystems for long period of time, altering their chemical forms to achieve significant risk level that threaten species through the induction of species intracellular and DNA damages, metabolic and organelle dysfunctions, metalloproteins displacement and the inappropriate activation of gene expressions (Tokar et al., 2015), with high likelihood of extinction threats to keystone species and other relevant biodiversity in the ecosystem. Hence, to address the current biodiversity pressure due to metal mining, there is need to put conservation into metal production perspective and develop model that would serve as pressure indicators in assessing the degree of distribution and nexus of natural resources mining and biodiversity crosslinks while integrating information on habitat condition and production level on scales that can be measurable.

The application of spatial analysis of mining on biodiversity pattern of distribution and habitat infringement and the perceived pressure in mining environment in the Philippines was conducted using secondary and primary data collection, spatial analysis and the generation of intensity index in order to assess the impact of mining metals on the biodiversity of the country with about 30 million total land area in hectares; of which 9 million hectares identified as having high mineral potential according to the Department of Environment and Natural Resources of the Philippines. The islands hold more than 52,177 described species with more than half reported as endemic. In Asia, efforts and coordinated strategies are on-going to enable data sharing and integration across several multidisciplinary arenas in order to monitor the gradual loss of biodiversity (Yahara, 2009) and the use of GIS to improve the internal workflow in field observation is critical to this goal (Ibrahim, et al., 2012).

The evolution of biodiversity monitoring scheme goes back to the early 1960's and since then, significant efforts have been devoted mostly on the developed economies (McGeoch et al., 2010, Martin et al., 2012, Hudson et al., 2014). Mainstreaming such positive development into the developing world would entails both intensive and extensive monitoring schemes including normalizing practices aiming at mainstreaming biodiversity as analyzed through the United Nation Environmental Program UNEP by Moldalieva, 2018. These would be vital to achieving a global mandate for effective biological diversity response to environmental changes; however, Proenca et al., 2016 stress the need for data integration from different data sources to enhance the global datasets. It is observed that Land use and related spatial pressures cause the largest biodiversity losses (Harry et al., 2017). Fischer et al., 2007 described species-oriented as although more daunting as it requires the detailed study of individual species in a given landscape but could lead to better established ecological casualties and functional relationship that are easily ignored using pattern-approach alone. To augment ground information biodiversity data gathering with satellite imagery, Luque et al., 2018 sees huge opportunities in using spatio-temporal resolutions and scales provided by satellite system for biodiversity planning and management in a much larger scale and this could help real time assessment and evaluating changes and implementing monitoring in biodiversity as they are impacted by mining operations and such capability can also be offered by both structured and unstructured biodiversity big data if properly analyzed (Bayraktarov et al., 2019).

The site-level geo-spatial analysis of species distribution using both the mining factor and biodiversity factor to generate the intensity index known as MintBio from three mine sites located in Itogon and Tuba, Benguet Philippines is the aim of this study. GIS workflow for ecosystem modeling and scalable observation spatiotemporally was used to strengthen data visualization as recommended by Nagendra et al., 2013.

The lifespan of a mine is usually between 20 to 100 years, and those of mine located in Benguet are not exception. Therefore, initial effort has to be made to document all the species living within the given areas of operation. With this, this paper proposes not just species count but their distribution across space and time, and by using GIS point layering to show their distributions, extent of occurrence and areas of occupancy in accordance to the IUCN Red list parameter. As an overview, Fischer et al., 2007, conceptualized a framework for understanding the effects of habitat pressure on species and assemblages, their threatening processes effects on the individual species and how they are perceived and interpreted. The framework offers an integrated approach to monitoring ecological pressure in order to avoid extinction cascade. Species oriented approach is relevant since each species would have to respond individualistically to their environment (Manning et al., 2004) and so such would now be used to account for changes in their mutualistic behaviour and also a host of deterministic and stochastic threats, which are not directly studied by few years' observation. Pattern-oriented maps the species' area relationship and the uses of biodiversity proxies like the land cover and protected area for conservation measure remain the widely used concept. In order to review the effect of losses in the structural elements of habitat and the living organisms hosted within in mine fields, one must first use GIS analysis of the spatial distribution of species in their patches within the mines. This is critical for an effective ecological restoration and management to be achieved during rehabilitation and more also, such an anomaly as to be accounted for and included as an intensity index in a scalable quantity to the material mined. Thereafter, mainstreaming biodiversity and defining the threats via measurements and attribution values; these are some of the on-going policy strategies proposed in many academy researches (Sylvia et al., 2017), here, they discuss some vital mainstreaming opportunities aided by sound governance and areas where they would matter most and one of them is in the mining industry.

The Philippines is one of the biodiversity hotspots in the world, with a spectacular geological and biogeographical evolution characterized by ancient land movements, sharp environmental gradient along steep volcanic slopes that initiated specific habitat assemblages and the geological sea level induced alterations of connectivity among neighboring island; 7,100 in total (Brown et al., 2007). The Philippines also has a record high species endemism nested within the Y-junction hotspot, linking Wallace's Line and Huxley's Line of the Southeast Asian and Australasian land masses (Brown, et al., 2007). The Philippines is scaling up its metal production in nearly all its regions and out of the 30million hectares total landmasses of its islands, 9million hectares is considered to be mineralized. Attempts to catch-up with the global trend for economic development over resources conservation has resulted to excessive resources consumption patterns across all economic sectors. In many sectors contributing to the global habitat and change and the associated pressure, mining is considered a key negative driver on biodiversity (Kobayashi et al. 2014). However, manufacturing and Extractive industries are mandated to effectively and honestly report the impact their production processes have on the ecosystem. Products life cycle assessment is one among the myriad ways by which companies show their commitment to environmental sustainability (Kobayashi et al., 2014). What's more, most mine sites are located in areas with minimal presence of fauna as compared to the flora richness, however, during operations, plants have less ability to migrate except during dispersal which are usually seasonal and as such have higher vulnerability to habitat pressure as a result of disturbances (Hobbs and Yates, 2003). For instance, plants pollination can be affected as a result of habitat pressure (Ricket et al., 4004).

The significance of this study is as follow; firstly, there is need to close the gap using large scale monitoring system. Since the biodiversity factor used in many studies is partly based on the protected areas categories, this has been heavily criticized to constitute less or contribute less towards meeting the challenges posed by stressors on biodiversity and therefore could fail to account for the real value that would result in model or framework designed to mitigate pressure or habitat modifications, for an effective and efficient global conservation. This assertion helps explain why countries with heavy local mining impact on biodiversity, still couldn't have high mining footprint when analyzed with biased global biodiversity indices. For instance, the global site analytic study conducted by Kobayashi 2014, considered the Philippines biodiversity not have been affected by the mining operation simply because the mining companies in the country are not operating within protected areas according to the global database. However, (Rodrigues et al., 2003) highlighted the need to consider other areas not listed as very large protected areas in that they hold the key to the vitality of the enlisted ecosystems; Large protected areas' contribution is questionable owing to their limited number globally and their less vulnerability to threats. Secondly, habitat lost and fragmentation due to mining operation are threat to species around mines in the Philippines, these negative drivers of change affect the country's biological diversity, and therefore would necessitate an attribution value or an index as an intensity indicator associated with the metals produced in the mines analyzed in the study. Third, since it is hard to quantify the exact weight or burden metal exploration and production has on biodiversity, the intensity index generated in this study would help inform and support design engineers to synthesize the amount of environmental pressure per unit weight of a material to be used. Such data would now be used as a guide for green choice driven supply–chain analysis, traceability and design and also could serve as an attribution value placed on metals to be monitored and identified by the blockchain platform which currently has proven to hold a promising potential for proof of green supply chain and eco-monitoring capabilities. As recommended by the 2012 EPS PEAKS study; there is need to provide evidence on how ecological cost associated with mineral resources extraction are managed, and by integrating cutting-edge strategies and natural capital accounts, as well as incorporating specialized support and standards models for species impact analysis on operation sites, such goal can be achieved (Bloom et at., 2012), more also, the challenges of providing the proper matrix and measuring indexes explained in the analysis of Moldalieva 2018 from the UN Environment World Conservation Monitoring Centre (UNEWCMC) report which recommended integrated data and tools as means of actualizing such matrixes. Hence, an intensity index; which is performance driven and not process-based- measuring the value of the maximum pressure a mine site or the metals it produces has on biodiversity could be used to achieve PEAKS's and (UNEWCMC)'s goal and purpose and that's what this study is about.

DESIGN AND METHODOLOGY

MintBio is a product of the mining factor and the biodiversity factor of mine X, Y and Z divided by the Fibonacci Extinction Factor. Mining Factor is the Annual Production values divided by the Percentage Grade of the ore produced in the mine (Kobayashi et al., 2014). However, instead of using biodiversity principal proxies in databases such as protected areas covered by the IUCN and land cover alone, local scale variables are used in this study; to establish an intensity index, an attribution value has to be generated based on relationships among multi-variables within the mines. The dependent variable MintBio index proposed in this study was obtained using python programming language to generate a multivariable calculus/summation from the mining factor and biodiversity factor. Fig 1 below shows the framework and flow of study.

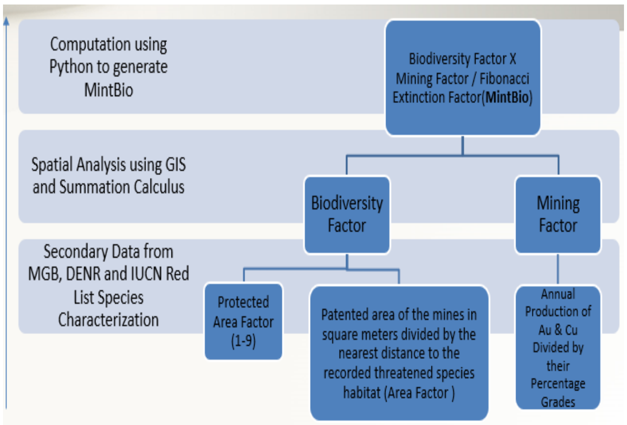

Figure 1

The Computational Flow and Framework for generating MintBio

Quantifying mining footprints on biodiversity would necessitate but not limited to; geospatial analysis, species counts and statistical testing. Gold and copper production values and grades were obtained from the dataset of the mining companies' databases, spatial or geographical variables from GIS mapping and plants geographic distribution patterns in the mine areas were also from secondary data sources (Herbaria collections of the endemic and threatened flora within study areas). Field study was not necessary since the spatial resolutions of the mine sites were obtained via remote sensing maps generated from the Department of Mines and Geosciences Bureau of the Philippines (MGB), and the geographical extent of each mine's operations were estimated using QGIS area computation and grid summation. The Mining Factors (MF) were obtained from the most recent mining database in the MGB database (2015 to 2017); this is calculated as annual production output of the mines divided by the percentage grade of the mines (Equation 1 and 2 and 8). In addition to the geographical ranges of the plants' distribution as they appear within the mines (Area Factor) proposed in this study, protected area and land cover databases of the region would be used to generate biodiversity factor as recommended by Kobayashi et al., 2014, (Equation 3 and 6). The intensity index MintBio proposed was generated using Jupiter notebook as the Integrated Development Environment (IDE) of python programming language (Equation 4-, 5 and 7) It expresses the mining footprint on biodiversity based on per kilogram of Gold and Copper mined in Mine X, Y, and Z located in Itogon and Tuba area of Northern Luzon Philippines. The mine sites are real as indicated in their coordinates however, their names were withheld due to patent reasons.

Although protected areas are principal ecosystem buffer zones and could be sorely used as principal habitat areas as dynamic ecosystem structural components and their respective functionalities, Area Factor was an additional variable in this study because most mines that are not located in protected areas can still endanger certain species of plants and animals. Protected Areas are usually categorized based on their richness and a priority number assigned by the IUCN. The Fibonacci Extinction Factor (FEF) used in this work is based on series of numbers that add up sequentially in a way that would indicate an increment in intensity that would cause the extinction of species.

FEF is defined as the Fibonacci Extinction Factor. It's the power to which a species is most likely to go into extinction as it lives within the zone of influence (Buffered as 5km) from the mine centre. It was obtained by dividing the species AOO by its EOO. This value is then powered to the Fibonacci Sequence 1, 1, 2, 3, 5, 8, 13, 21 ...; corresponding to the evaluated species in red list of IUCN having an increasing extinction factor from vulnerable through endangered to extinct. The IUCN 2017 Red list category is used for the characterization of each taxon documented with their corresponding FEF. Such numbers have been proven to be followed by so many natural designs such as the in petal counts or in pine cones, etc. The generated intensity index; MintBiofl/fa has to be defined as an intensity value per unit of produced gold and copper mined in site X, Y, Z as shown in the succeeding equations, maps, and tables below.

Mathematical Modeling of MintBio

MF is the Mining Factor and BDF is the Biodiversity Factor.

For Gold,

$\mathbf{MF_{Au} = AP_{Au}/\%G_{au}}$ ....1)

Therefore, for mines with more than one mineral production,

$\mathbf{MF_m} = \sum_{n=1}^{m} n\, AP_m/\%G_m$ ....2)

And

$\mathbf{BDF_{fl/fa} = BDF_{fl} + BDF_{fa}}$ ....3)

$\mathbf{BDF_{fl/fa}=AF*PAF}$; for flora/fauna distribution over the zone of influence generated in GIS layer. $\mathbf{FEF= (AOO_{fl}/EOO_{fl})^{FN}}$

$\mathbf{BDF_{fl/fa}=AF*PAF}$; for flora/fauna distribution over the zone of influence generated in GIS layer. $\mathbf{FEF= (AOO_{fl}/EOO_{fl})^{FN}}$

Where **FEF** is the Fibonacci Extinction Factor and FS is the Fibonacci Numbers assigned to the threatened species.

$\mathbf{MintBio = MF*\ BDF/ \sum FEF}$ ....4)

and;

For Copper,

$\mathbf{MintBio_{cu} = MF_{cu}*\ BDF/ \sum FEF^{-}}$ ....5)

One mine site BDF = AF*PAF...............................6)

For Gold,

$\mathbf{MintBio_{Au} = MF_{Au}*\ BDF/ \sum(AOO_{fa/fl}/EOO_{fa/fl})^{FN}}$ ......7)

If $\mathbf{FEF = (AOO_{fl}/EOO_{fl})^{FN}}$

For a Mine Y producing only Copper (Cu)

$\mathbf{MintBio_Y = MF_Y*\ BDF / \sum FEF}$

But if mine Y produces more than copper,

$\mathbf{MF_Y} = \sum_{n=1}^{y} n\, AP_y/\%G_y$ ....8)

RESULTS

Table 1

The Mining Factor of mine X, Y and Z generated from their annual production values and the percentage grade.

Mines	Year	Gold(Au) Qty- kg	% Grade of Au	Copper(Cu) Qty-kg	% Grade of Cu	Mining Factor(Au)	Mining	Factor(Cu)
X	2017	2632.55	0.349	64711	0.192	7543.123	337036.46	
X	2016	3213.14	0.421	73109	0.199	7632.161	367381.91	
X	2015	3355.92	0.431	69988	0.206	7786.357	339747.57	
				Silver(Ag) Qty- kg				
Y	2017	214.01	6.18	84.74		34.629		
Y	2016	77.27	6.9	75.06		11.199		
Y	2015	378.41	8.58	170.9		44.104		
Z	2017	56.29	5.31			10.601		
Z	2016	29.22	6.34			4.609		

Design and Calculation of MintBio. The product of Mining Factor and Biodiversity Factor divided by the Fibonacci Extinction Factor generates MintBio.

Table 2

FN is Fibonacci Number used to generate Fibonacci Extinction Factor (FEF); It is obtained from the Area of Occurrence of endangered species (AOO) divided by the Extent of Occurrence (EOO) raised to the power of FN(1,1,2,3.. 13..+n) depending on the category which the species belongs.

Fibonacci Numbers	Taxon Classifications from IUCN RED List Categories	Probability of Extinction
13	Endangered and Endemic (Crically Endangered)	50% within 10 years
8	Endangered but not Endemic (Endangered)	20% within 20 years
5	Threatened and Endemic (Extremely Vulnerable)	10% within 100 years
3	Endemic and Vulnerable (Threatened)	10% within 100 years
2	Near Threatened but not endemic	-
1	Not threatened and not endemic (Least Concern)	-
1	Data Deficient	-

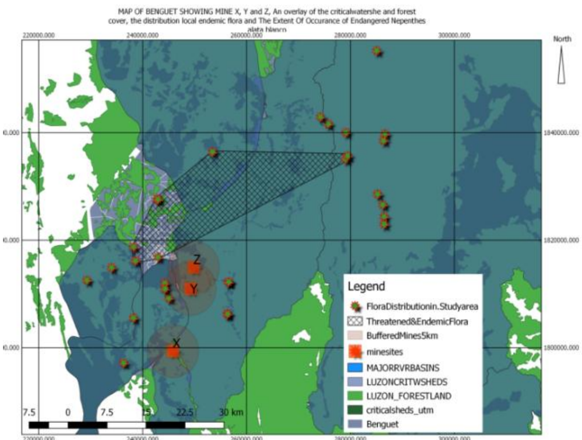

Figure 2

GIS-generated Layers of Study areas and the flora distribution (See Legend for guide)

Area Factor is the patented area of the mine in square meters divided by the nearest distance to the documented threatened species (flora or fauna). This area is considered to be the entire operational area of the mines. Table 2 below shows the patented areas of mine X, Y, Z and their corresponding Area Factors in meters.

Table 3

The Area Factor of mine X, Y and Z computed from the patented claim areas in m2 divided by the closest distance from mines center to the closest threatened flora in meters

Mines	Patented Claim Area(m^2)	Species	IUCN Status	Closest Distance away from the mine center to the threatened flora(m)	Area Factor
X	806,668	*Pterocarpus indicus, Lilium philippinese*	Vulnerable and least concern	9,616.21	83,836
Y	1,365,832	*Nepenthes bellii, Shorea polysterma*	Endangered and critically endangered	4,200.33	325,172
Z	352,638	*Lilium philippinese*	Least concern	7,100.10	49,667

The Annual production of Gold and Copper and their respective percentage ore grade are used to generate the Mining Factor of the mines. These values are shown in the table above.

Table 4

The MintBio index values of gold and copper in mine X, Y and Z

Mines	Year	MF	PAF	AF	FEF	MintBio
X	2017	7543.12	3	83.886	None	1,898,287.25
	2016	7632.16	3	83.886	None	1,920,694.37
	2025	7786.36	3	83.886	None	1,959,499.03
Y	2017	34,629	3	325.17	0.00033	103,941,980
	2016	11,199	3	325.17	0.00033	33,614,780.60
	2015	44.104	3	325.17	0.00033	132,382,024
Z	2017	10.601	3	49,667	None	1,579.56
	2016	4,609	3	49.667	None	686.756

$\mathbf{MintBio_{x/y/z} = MF_{x/y/z} * BDF_{x/y/z} / \sum FEF_{x/y/z}}$

For mines producing more than one mineral, $\mathbf{MF_m} = \sum_{n=1}^{m} n\, AP_m / \%G_m$ must be used.

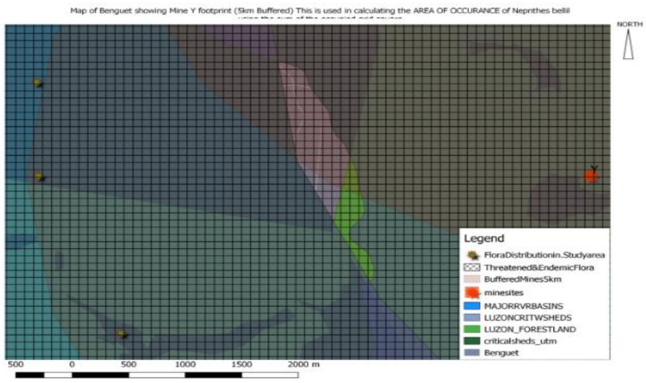

Figure 3

GIS-generated map of Mine site Y and the distribution of Nepenthes Bellii and Shorea polysterma within its zone of influence (See Legend for details and guide). To generate the AOO and EOO, see Fig 4 bellow

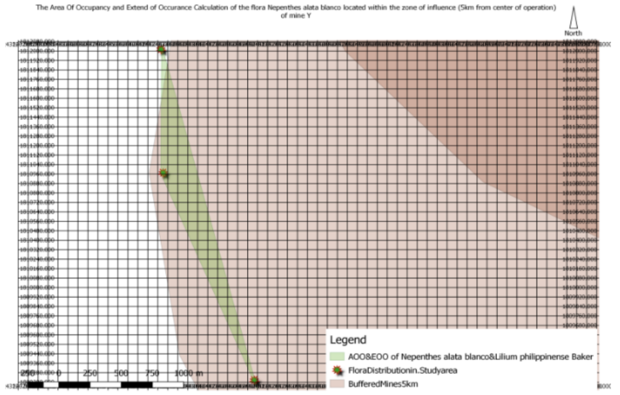

Figure 4

AOO and EOO are calculated from the sum of the grid squares of the flora and the value of the entire area that the floras were seen and recorded using GPS within the mine site.

The Extent of Occurrence and area of occupancy can be seen in the taxon distribution pattern across the sites. In accordance with the IUCN Red list criteria, the two geographical ranges can be measured by a minimum convex polygon with less than 1800 angle containing all the taxon and the sum of the occupied grid squares define their area of occupancy respectively. With these, a quantitative analysis becomes necessary in order to measure and estimate the probability of extinction of the taxon based on the documented life history, habitat preferences, threats and the specified management options given to the taxon in the site. This can be done using Population Viability Analysis (PVA) as recommended by the IUCN. The degree of fluctuation in the above geographical range measurements have to be observed and documented. The concentration of heavy metals in the tailing and acid mine drainage released from the mines could pose threat to the species living near and even far away from the mines and using the potential ecological risk index developed by Hankanson, (1979) would be the closest possible threat indicator from these mines and to obtained this value, the concentration of these potential DNA and cell/tissues damaging heavy metals would be considered as established by many researchers Chengxin etal., (2004); who pointed out that pollution sources and extent could be reflected in sediments receiving contaminants through water pathways. It is on this basis that the sum potential ecological indexes of the heavy metals obtained from nearest steam sediments at the vicinity of the mines should be multiply by the mining factors and the biodiversity factor and the resulting values divided by the conservative factor to generate the final MintBio index values.

The value of the MintBio of gold and copper obtained in this study as shown in table 4 ranges from 686.756 from mine Z to 33,614,780.60 of mine Y indicating vast differences that were captured due to the higher threat of mine Y to the endemic and threatened species within 5km from the mine center. This is an interesting indication of sensitivity to the biodiversity factor which varied from mine to mine and as such robustness in value could be used as an indicator for monitoring mines with high biodiversity impact and to pay attention to mines with unimaginable intensity index. For example, Mine Y is having huge biodiversity impact due to the presence of Shorea polysterma and Nepenthes Bellii which are critically endangered and endangered respectively in the IUCN Red list category and are found within the radius of influence from the mine's centre. The inclusion of conservation and pollution factors would further increase such sensitivity for higher performance.
It is clear that the magnitude of impact for mining a specific metal is approximately regarded by many intensity assessment studies to be the product of the extent and intensity of its operation has on the ecological functions and structures of the species within the site. MintBio indicates mining pressure in form of an index on flora within study area; this could be used to set target and prioritization for mining regulations. Hence, the index can be used to identify mines that should receive special attention, to quantify to the tinniest of scales the ecosystem and species diversity that are often ignore using large scales monitoring/variables and biodiversity proxies during impact analysis, this index could also be used for corporate reporting and international corporations financing, for corporate management in eco-designs, eco-labelling and international standardization for material options leading to a better policy option- either to improve conservative measures and scheme on the country's biodiversity, to implement more no-mine zone areas in the Philippines as stated in the Executive Order 79. MintBio could serve as a comparative index analysis of different mines in the country as well as mines across the globe for biodiversity assessment and management within mining areas.

Statistical Tests for Results. The linear regression functions in Microsoft Excel data analytical tools were used to test for the relationship between MintBio obtained from the three mines and the independent variables are Mining Factor, Area Factor, and the proposed Fibonacci Extinction Factor. The results are displayed below in table 5, 6 and 7.

Table 5
MintBio is independent of Mining Factor as indicated in the p-value of the linear regression output.

SUMMARY OUTPUT

REGRESSION STATISTICS	
Multiple R	0.990399
R Square	0.98089
Adjusted R Square	0.977705
Standard Error	228.0153
Observations	8

ANOVA

	df	SS	MS	F	Significance F
Regression	1	16011571	16011571	307.968	2.20E-06
Residual	6	311945.9	51990.98		
Total	7	16323516			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	140.0604	102.2475	1.377719	0.21747	-109.322	391.059	-109.322	391.0591
Mining Factor (Au)	0.382796	0.021813	17.54902	2.20E-06	0.329421	0.43617	0.32942	0.43617

As shown in table 5, MintBio can be used to analyse different mines regardless of their economic scale. This result was in consonance with the MiBiD index generated by Kobayashi et al., 2014. And therefore, MintBio could serve the Philippines Biodiversity monitoring agency to compare mines with low to high biodiversity impact without looking at the scale of their production, however, percentage grade of ores shows a strong negative correlation with MintBio indicating grade as a vital variable to consider in order to operate a mine in biodiversity-rich areas. The regression analysis of MintBio on AF and FEF shows a significant value of 0.027705 and 0.027632 respectively (See table 6 and 7). Meaning MintBio is highly dependent on these two variables and as such could be used to assess the impact of mines on biodiversity. This significance level is an indication of how AF and FEF are species-oriented distribution parameters as they are capable of influencing the rate of change of MintBio.

Table 6

MintBio is significant with AF while MF remains insignificant.

SUMMARY OUTPUT								
REGRESSION STATISTICS								
Multiple R	0.860739							
R Square	0.740872							
Adjusted R Square	0.637221							
Standard Error	32168626							
Observations	8							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	2	1.48E+16	7.40E+15	7.14774	0.034181			
Residual	5	5.17E+15	1.03E+15					
Total	7	2.00E+16						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-1.60E+07	27061791	-0.60356	0.57247	-8.60E+07	53231211	-8.60E+07	53231211
MF	-1188.44	3575.374	-0.3324	0.75307	-10379.2	8002.352	-10379.2	8002.352
AF	327023.8	106435.6	3.0725	0.02771	53422.41	600625.2	53422.41	600625.2

Table 7

MintBio is significant with AF while MF remains insignificant.

SUMMARY OUTPUT								
REGRESSION STATISTICS								
Multiple R	0.860888							
R Square	0.741128							
Adjusted R Square	0.637579							
Standard Error	32152751							
Observations	8							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	2	1.48E+16	7.40E+15	7.15727	0.034097			
Residual	5	5.17E+15	1.03E+15					
Total	7	2.00E+16						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	900000599	18569757	4.84662	0.00469	42265519	1.38E+08	42265519	1.38E+08
MF	276.2971	3837.797	0.07199	0.9454	-9589.07	10141.67	-9589.07	10141.67
FEF	-9.00E+07	29307084	-3.07482	0.02763	-1.70E+08	-1.50E+07	-1.70E+08	-1.50E+07

DISCUSSIONS

The existing attribution indexes and other intensity markers used to account for the pressure that production processes have on ecosystem by tracing the origin of products from their point of production to final use and disposal using country scale isn't robust enough to capture the micro-scale and the interactions within the ecosystems nesting these operations spatial-temporally, they also lack the incentive variable to trigger biodiversity offsetting and regeneration programs. A unified model for such a fine-scale resolution analysis would be important to achieve the above objectives. The question as to how mining processes perturb flora and fauna distribution, and their survival can be answered by assessing the pressure with consideration to the species distribution within those mines and how a scale up in one or two of the variables can lead to sustainable and responsible mining in biodiversity context.

Such pressure index has to be used to mark out the intensity each mining site has on biodiversity and could be used to generate an intensity index to verify impact, monitor and Validate sustainability claims regarding mining those metals via blockchain system's proof of green mechanism.

It is currently believed that blockchain solution and infrastructure have the potential to validate practices that would reward metal product buyers, designing engineers and manufacturers based on a proof-of-no biodiversity impact index on an immutable chain of codes on the metal product. This has the potential to shape better, responsible mining and metal usage as well as the goal of eco-friendly metal industrial system.

For this mathematical nexus to be developed and utilised to generate the attribution index between mines and biodiversity impact, and even to a scale of a kilogram of the metal, several variables have to be considered, calculated and used for mines monitoring, assessments and scalable management.

In addition to the MintBio developed from the threatening variables, it is important that offsetting as a parameter be added as the number of threatened species to be conserve adds up during the company's conversation activities. It is needed as a variable to account for measures taken to improve species amount. The moment the mining company implement offsetting mechanism or any other program to increase the number of threatened species; the conservation factor or variable would be deducted from the value of MintBio and the value of the index drops to account for the regeneration process implemented. Same procedure can be done on pollution control from the mine under investigation.

MintBio is framed as a response to integrate mathematical and spatial modeling for biodiversity protection driven by excessive consumption patterns which keeps blurring the lines between human activities and his uses of natural resources, a chief among them is metal demand for infrastructure development. To be successful in indexing these changes, researchers and regulators are now being warned to continuously adapt to new, fast-changing environment, reinventing models and adopting innovative and strategic systems so they can truly keep pace in addressing the emerging global environmental challenges. MintBio is inspired by the constant need for interdisciplinary approach towards problem solving related to ecosystem assessment and management via a robust up to date research on theoretical and disturbed ecology, mines production scales, grades and geo-spatial analysis, species spatial distribution; informed by the spatial species distribution using GIS within the framework of the IUCN Red list methodology for areas occupied and the extent of occurrences or threatened species, improvement in clean productions initiative via green claim validation, biodiversity conservation and computer modelling.

This model opens new areas for researchers to explore possible connection between mineral production and biodiversity as well as other anthropogenic activities within areas rich biodiversity and the assignment of attribution index to label the cost of the production and utilization of large ecological footprint products and the green score (lower MintBio values) for those with lesser or no impact in order to achieve sustainable resources management.

Limitation of the Study. Data of the threatened fauna distribution across the mine's sites were lacking and so could have enhanced the MintBio as an effective intensity index across larger area in mining communities where biodiversity abounds. More also, the data on the endemic and threatened flora were sparse and field sampling would have further strengthened this study to a large extent. MintBio is based on ecological disturbances as a result of mining gold and copper within the study area and as such could not account for the other metals produced in those mines. However, by adding up the other metals annual productions and grades, one could utilize summation calculus to generate intensity indexes on biodiversity using the same biodiversity factor analyzed and obtained within the mines via GIS. The inclusion of the conservation factor (CF) that would stimulate species increment through off-setting scheme, tree planting or other positive measures the mining companies would implement. CF was not used in this study, however off-setting the CF would drastically reduce the MintBio values and thereby scaling the company's conservative input into record. It is noteworthy to also point out that pollution from the mines could undermine species diversity across space and time and by integrating the intensity or pressure from pollution impact from mines which lack the capacities to contain their tailings would enhance MintBio. Finally, MintBio is based on terrestrial mining of metals and might not be applicable within deep-sea environment with high sensitivity to mineral exploration and production.

Conclusion and Recommendations. Through habitat lost, fragmentation and contaminations, metals production attribution to species threats is a well-established research evidence, with capabilities to induce negative species reproductive and social behavior, intracellular and DNA damages, metabolic and organelle dysfunctions, posing a huge species extinction threats to biodiversity. Our tool (MintBio indexes) provides tangible blockchainable solution by using spatial data based on ground observations information to develop a mathematical model that captures the potential threats to biodiversity from mining activities in order to foster a better understanding toward attribution of metal mining impacts on biodiversity and conservation management through green validation technology. MintBio is an intensity index that can be used to assess the impact of mining metals on biodiversity within the mine sites. It is generated from the geospatial impact analysis using QGIS, site-specific sampling and data integration and finally statistical testing using the variables obtained from mine X, Y and Z in Itogon and Tuba area, Benguet Philippines. If by chance via desk study or field sampling, a degree of sensitivity is confirmed, the chances of threat and future endangerment would be high due to the mining operation within such area and as such, should not be allowed to operate or be given less area and extensive buffer zone to minimize threat to biodiversity and the associated ecosystem services offered by the area for ecosystem and human well-being.

By relating the mines area of operations in meter squares to the extent to which their proximity impact species diversity as they are distributed across space, site-specific biodiversity assessment study is highly recommended in order to confirm biodiversity features and detail species distribution pattern. We would recommend more data on the flora and fauna distribution to be collected using GPS devices especially on the threatened species in order to effectively use the model as intensity index indicator. For further studies, data on marine species distributions within areas rich in mineral resources should be undertaken and fauna data which were lacking in this study would enrich MintBio. The conservation factor is needed to improve MintBio in order to serve as an incentive driver for index scores, stimulating conservation measures like tree planting, protection area and off-setting scheme. More also, the impact of pollution from the mines can enhance the intensity and for such to be relevant, the edge effect of mines on species distributions has to be considered.

Finally, MintBio is a potential source of information for the emerging blockchain technology with capability of storing, decentralizing and validating production processes and the final use of products in order to stimulate green production and halt the extraction, distribution and supply of metals from mines with high biodiversity pressure. It is also relevant that MintBio be trained using country-specific mines variables and used to compare those of other countries. Training the model to accept more information as more data become available would help avoid under fitting and over fitting using regression algorithm in order for it to be used as metal production footprint on biodiversity management software with application programming interface to blockchain system. This will help build a framework for regulators and other relevant stakeholders. Finally, MintBio can be integrated into satellite remote sensing digital information system; offering relevant agencies the capability to infer species richness and compositional turnover to address the measurement and monitoring of species under threats as a results of mining footprint in real time.

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