Paper Draft

Cost efficient development of nature-based impact assessments

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Introduction

Environmental Assessment (EA), a participatory *ex-ante* assessment framework for policies, plans, programs and projects, was created in the USA by the National Environmental Policy Act (NEPA) in 1969. Subsequently, it spread widely to jurisdictions of other countries, not just as EA (encompassing both, environmental impact assessment (EIA) of projects and strategic environmental assessment (SEA) of policies, plans and programs; but increasingly also as Health Impact Assessment (HIA), Social Impact Assessment (SIA) and numerous other types of impact assessment (IA) (Fischer *et al.,* 2023).

Known for being expensive, complex, long and ineffective to protect the environment for ongoing activities, EA/IAs are being target of simplification efforts. These initiatives frequently appear to relate to changing political agendas and responses to economic downturns (Bond *et al.* 2014). In this context, this paper aims to provide useful information regarding cost efficient methodologies to assess common environmental impacts, in a way typical datasets/surveys can be complemented without much more effort or even replaced.

Air pollution Impact Assessment

Air pollution is one of the main issues existing in urban areas, being characterized by the presence of toxic gases and metal pollutants, the latter of which is generally associated with emissions of particulate matter (PM) from industries or automotive vehicles.

Biomonitoring is a method that can be used to assess air pollution levels because it makes it possible to determine what effects these air pollutants cause in living organisms and their responses. The species *Lolium multiflorum*, known as ryegrass, is considered a good bioindicator of metals, since it accumulates these substances during exposure (Illi *et al*., 2016).

In a study in southern Brazil, ryegrass individuals were grown in a controlled environment and then exposed to four locations with different degrees of urbanization, besides a control site (CS): a semi-urban area - 10 km from a highway and urban areas - 5 km, 200 m and 60 m from the highway. PM 2.5–10 and PM2.5 were collected monthly for 24-h periods at the sampling sites and particles were identified by scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS).

At the Control Site (CS), all the metallic elements analyzed showed medians lower than the values identified at the other sampling sites. In general, Al, Fe, Mn, Zn, and Ba showed the highest median values in all the four sampling sites.

Using Principal Component Analysis (PCA), it was possible to identify three principal components, labeled as follows: PC1 - Earth's crust (strong positive loadings for elements Fe and Al and associated with natural sources of emission, such as resuspension of dust from the soil), PC2 - traffic/industry (association with the elements Cu, Zn, and Ni and related to vehicle and industrial emissions, such as combustion of fuels, abrasion and wear of metallic parts, and industrial processing of metals), and PC3 - traffic (characterized by the presence of Ba and Mn, and to a lesser extent Cr, and related to abrasion and wear of metallic parts) (Illi *et al*., 2016).

The different levels of anthropization, identified at the four sampling sites, demonstrated the degradation of air quality as well as the effectiveness of the use of bioindicators (i.e., *L. multiflorum*). Furthermore, the use of *L.*

multiflorum is a low-cost method, easy to apply, and can be used worldwide as an evaluation tool of the effects of air pollutants in urban, semi-urban, and rural areas and can be used complementarily to other standard methods of investigation of air quality (Illi *et al*., 2016).

Traditionally, air quality mapping involves equipment or station allocation to explore data and high costs but usage of biomonitoring to explore locations is an easy and simple solution to identify hotspots to concentrate efforts in areas of need, which can be later monitored by standard methods for confirmation and detailing.

Biological Signature - Fauna and Flora Survey using eDNA

Environmental DNA or eDNA describes the genetic material present in the natural environmental as sediment, water, and air, including whole cells, extracellular DNA and potentially whole organisms (Ruppert *et al.,* 2019).

eDNA can be captured from environmental samples and preserved, extracted, amplified, sequenced, and categorized based on its sequence. eDNA may come from skin, mucous, saliva, sperm, secretions, eggs, feces, urine, blood, roots, leaves, fruit, pollen, and rotting bodies of larger organisms, while microorganisms may be obtained in their entirety (Ruppert *et al.,* 2019).

Despite being a relatively new method of surveying, eDNA has already proven to have enormous potential in biological monitoring. Conventional methods for surveying richness and abundance are limited by taxonomic identification, may cause disturbance or destruction of habitat, and may rely on methods in which it is difficult to detect small or elusive species, thus making estimates for entire communities impossible (Ruppert *et al.,* 2019). eDNA can complement these methods by targeting different species, sampling greater diversity, and increasing taxonomic resolution (Deiner *et al.,* 2017).

This process involves metabarcoding, which can be precisely defined as the use of general or universal polymerase chain reaction (PCR) primers on mixed DNA samples from any origin followed by high-throughput next-generation sequencing (NGS) to determine the species composition of the sample (Ruppert *et al.,* 2019). This method has been common in microbiology for years, but in recent years it has been used to assess macroorganisms.

Ecosystem wide applications of eDNA metabarcoding have the potential to not only describe communities and biodiversity, but also to detect interactions and functional ecology over large spatial scales. It also presents superior species detectability, requires lower effort, causes no ecosystem disturbance, allows detection without a priori knowledge of species, and can be implemented in areas where traditional surveys are impossible (Ruppert *et al.,* 2019). Limitations, however, may be linked to false readings due to contamination or other errors.

Metabarcoding can be used to reconstruct ancient ecosystems from DNA found throughout the world, to explore the interconnectness between plants and pollinators, to assess diet without need for feeding observation or stomach flushing, to detect invasive species before they could possibly be detected via traditional means, to determine community responses to pollution, and even to assess air quality and its implications for human health (Ruppert *et al.,* 2019).

In addition to the biological signature, the chemical signature can also be used to identify the contribution of a certain process/activity, whether natural or not, in the environmental matrices. As an example, there is the chemical composition of sediments, which can be used as a simplified tool for managing watersheds.

Statistical methodology to simplify monitoring of mineland rehabilitation status

Impact of mining operations are mitigated by Ecological restoration, in which is developed a partial restitution of biodiversity and ecosystem structures, functions and services of original ecosystems. To monitor status through time many environmental variables are assessed, representing herculean effort of analysis, manpower and resources. In an iron mining in Carajás National Forest, eastern Amazon, Brazil, was developed a study with the objective to select potential indicators of environmental quality of iron mining waste piles undergoing rehabilitation.

Among 27 variables, including vegetation structure, community composition and diversity, and ecological processes, the Shannon index of tree diversity had the highest predictive power for overall rehabilitation status, qualifying this metric as the most effective indicator for the use in future comprehensive monitoring activities in waste piles undergoing rehabilitation in the Carajás National Forest; moreover, it will simplify and reduce the cost of more comprehensive monitoring activities in minelands undergoing rehabilitation in the future (Gastauer *et al.,* 2021).

The positive relationship between tree diversity and mineland rehabilitation status in the examined areas emphasizes the importance of diverse tree communities in increasing rehabilitation success and ecosystem and soil functioning over short time periods, showing it is a good bioindicator, but also highlights statistical methodology applicability in point out the most efficient variable to monitor (Gastauer *et al.,* 2021).

Statistically sound analyses to validate the selection of environmental variables for environmental assessments encourage similar approaches in cases without binding standards regarding which or how many environmental variables are required monitor rehabilitation or restoration activities. The identification of effective indicators to monitor rehabilitation activities may further contribute to more efficient environmental assessments in future monitoring projects (Gastauer *et al*., 2021).

Ecoacoustics

To quantify and monitor animal biodiversity, diversity indices are usually used, calculated from data obtained by conventional means of sampling, such as observation of footprints and traces, as well as capture and tagging, among others. However, these methods demand prolonged sampling time and effort, as well as substantial financial resources.

Ecoacoustics enables the study of biological diversity through the analysis of sounds in an environment, with low cost and easy data processing. Currently, Ecoacoustics is characterized by three basic components: biophony (biological sounds), geophony (ambient sounds) and anthropophony (sounds resulting from human activities), which enables analysis of the reflections of man's interactions with the natural environment.

By recording sounds, it is possible to identify the fauna of a given environment and obtain ecological indices. However, the acoustic indices are not enough to quantify all the animal diversity of a community, as some species are not sonorous or present an occasional and/or little diverse sound repertoire.

In a study by Soares (2023), it was designed a preliminary way to describe the different components of the terrestrial acoustic landscape of the Restinga Forests in the extreme south of Ilha Comprida, in the south of the State of São Paulo. The specific objective is to estimate the biological diversity from the different biophonic components. As a result, the presence of birds, insects, amphibians and mammals such as bats was observed.

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