Exploring the biodiversity in Alas Purwo National Park, East Java through soundscape ecology

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Abstract. Biodiversity assessment is becoming one important things to do, to conserve ecosystem. Biodiversity assessment’s new method was utilized the nature sounds which is produced by animals in an ecosystem. There are three possibilities sounds sources in an ecosystem, they are: biophonies, geophonies, and anthrophonies, those sound sources will reflect environment acoustics characteristics, called Soundscape. This paper utilized the Soundscape method to predict biodiversity in a forest. Alas Purwo National Park, Banyuwangi, East Java was the location where soundscape data were collected for several days. The soundscape data was processed using R-Statistical Computing Environment software to compute some index values of Bioacoustics Index (BIO), Acoustic Entropy (H), Acoustic Evenness Index (AEI) and Normalized Difference Soundscape Index (NDSI). These indices enabled to characterize the forest in Alas Purwo National Park, East Java, Indonesia for several types of forests selected. The AEI value of 0.69 indicate inequality between frequency bands. The BIO value of 10.79 indicate a forest that is dominant of biotic component. The H value of 0.88 indicate more diverse biotic components. The NDSI value of 0.97 indicate a forest that is dominant with biophonies rather than antrophonies. The results have indicated that some indices (AEI and BIO) could reflect the biodiversity in selected ecosystem, but other indices (H and NDSI) showed anomaly result because of difference landscape between selected ecosystem and ecosystem’s weather when data collecting period.

1. Introduction

Indonesia has a conservation area that aims to maintain the existence of forest area and its biodiversity. Conservation area is a natural ecosystem to be a shelter for flora and fauna [1]. The more advanced technology, caused human life will be more dynamic. The dynamics of human life covers for residential needs or industrial needs. Frequently, deforestation (forest removal process) become a choice to fulfilled the needs. In 2012-2013, deforestation in Indonesia counted 727,981.2 hectares/year [1]. Of course, with the increasing deforestation rates, the forests in the conservation areas will decrease.

Biodiversity assessment in an ecosystem is a major work for the field of biological conservation. Biodiversity assessment, nowadays, becomes an important work since the widespread deforestation that occurs. This assessment not only assesses the richness of species present in the ecosystem, but also sees changes in species within a given period [2]. Approach methods for biodiversity assessment have been developed before, from Rapid Biodiversity Assessments (RBA) to All-Taxa Biodiversity Inventories (ABTI).
Expeditions undertaken by researchers around the forest to do biodiversity assessment, these methods are inefficient in terms of quality, time and cost [2]. Ordered sounds of animals in a natural ecosystem, are often encountered in a complex natural ecosystem. The sounds can be a source of information to predict the diversity of animal communities (biodiversity) in a forest, if it is processed and analyzed further. Acoustic index in a natural ecosystem is expected to become a new method in biodiversity assessment approach.

The purpose of this paper is to perform soundscape in several types of forest ecosystems in Alas Purwo National Park. The results of the soundscape are processed further so that forest ecosystem’s characteristics can be known by using the acoustic index.

Utilization of acoustic data to predict biodiversity in an ecosystem had been done for the last decade. Initially, utilization of acoustic data was performed by Boelman, et al. (2007) to estimate the correlation between plant invasion and Aves occurrence in the Hawaiian Rainforest [3]. Then, Sueur, et al. (2008) offer a new method for describing biodiversity in Tanzania’s Coastal Forest, this method could represent the biodiversity in location and could reveal ecosystem differences based on degrees of vegetation [2]. In contrast to Sueur, Villanueva-Rivera, et al. (2011) offers different acoustic data processing based on the frequency domain [4]. The following research, performing acoustic data measurements and data processing as previous studies, in the different location of the case study, namely: Twin Lakes, Michigan [5]; Minas Gerais, Brazil [6]; Queensland, Australia [7][8]. In addition to its relationship to biodiversity, Fuller, et al. (2015) examined that utilization of acoustic data could reveal the landscape in the surrounding ecosystem [8].

The index used in soundscape ecology determined biodiversity and landscape conditions of an ecosystem. The Bioacoustics Index (BIO) became the first index introduced by Boelman, et al. (2007) [3]. BIO index used, at that time, to measure the spectrum in the Aves’ sound frequency range, in the range 2000 Hz to 8000 kHz [3]. In following research, Sueur et al. (2008) proposed an index that measure not only on one species of animal, but the entire biotic component of an ecosystem. To measure biodiversity in the ecosystem, Sueur, et al. (2008) used index Acoustic Entropy Index (H) and Acoustic Dissimilarity Index (D). Previous research was analyzed acoustic signals in time-domain, then Villanueva-Rivera, et al. (2011) analyze the acoustic signal using frequency-domain. This study referred to the hypothesis that each species of biotic component in a natural ecosystem has unique frequencies and unique active times that are different from one another. Villanueva-Rivera, et al. (2011) perform calculations to obtain an index to study an ecosystem, example: diversity index (called Acoustic Diversity Index (ADI)), evenness (called Acoustic Evenness Index (AEI)), and dominance over the frequency range. The results showed that the difference of point (location) of data retrieval will result in different index values. This approach method can be used as a material for spatiotemporal comparisons [4].

Pieretti, et al. (2011) review the index to measure the songs produced from Aves. This index was called the Acoustic Complexity Index (ACI), this index is claimed to be a new method for observing Aves despite anthroprophies or climate [9]. The previous indexes that proposed by investigators were still investigating the source of sounds derived from animals (biophonies), but Kasten, et al. (2012) states that acoustic data could also be a tool for knowing human presence (anthrophonies). Kasten, et al. (2012) performed Power Spectral Density (PSD) calculations for biophonies frequency range between 2000 Hz to 8000 Hz and anthropophies frequency range between 1000 Hz to 2000 Hz. The results of both PSD are then compared and become the index value of The Normalized Difference Soundscape Index (NDSI) [5].

The indices were also examined by Gage, et al. (2017) and Fuller, et al. (2015). They tried to measure biodiversity in Queensland, Australia [7][8]. Gage, et al. (2017) using the indexes (The Normalized Power Spectral Density, ACI, ADI, AEI, BIO, H, and NDSI) for the present soundscape metrics at Samford Ecological Research Facility in Queensland, Australia. The presentation using soundscape metrics will facilitate the correlation, and the results indicate that the number of species (dawn chorus) will correlate with the soundscape power in the range 3000 Hz to 4000 Hz and also correlate with the ADI, AEI, and H indices [7]. The correlation between the index and the number of species still had not
fulfilled the main objective of soundscape ecology, which can also describe the landscape of the ecosystem, so Fuller et al. (2015) conducted research using the indexes (ACI, BIO, H, ADI, AEI, and NDSI) at 19 different sites. Fuller, et al. (2015) correlated between the index results with the landscape at the location of the data. The correlation resulted that the index H, AEI, and NDSI are the best indexes to represent the landscape state of a soundscape, while the BIO and ACI parameters will better represent Aves richness in each forest type [8].

2. Methods
This study was conducted using primary data sources. The primary data source was obtained by taking sound recordings in several types of Ecosystem. Sound recordings were process to obtain soundscape ecology index and characterize each ecosystem using those indexes.

2.1. Recording Sites
The location for this research was in Alas Purwo National Park, Banyuwangi, East Java. In this National Park, there are several types of forest ecosystems that exist, namely: Coastal Forest, Mangrove Forest, Lowland Plantation Forest, Bamboo Savana Forest, and Plantation Forest. There are 3 types of forest ecosystem selected for this research, namely: Lowland Forest Ecosystem (tag A), Plantation Forest Ecosystem (tag B), and Coastal Forest Ecosystem (tag C).

![Figure 1. Point of recording sites in several types of ecosystem.](image)

2.2. Recording Duration and Tools
Data collecting period was conducted on April 19th, 2017 to April 23rd, 2017. Data collecting would record the environment sounds. For recording, we used mobile phones with external microphone and installed at each data point. The mobile phones had been installed with ARBIMON-Touch applications, this application will allow the device to record for 1-minute for every 10-minute interval. This timing scheme corresponded to the data collecting method used in the previous research.

2.3. Recording Duration and Tools
Data processing use functions in ‘seewave’ and ‘soundecology’ that installed in R-Statistical and also Microsoft Excel 2013. R-Statistical allowed to process audio file into the indexes values. To processed such a big data, function multiple_sounds will process all the audio file in a folder at a time. Output from the multiple_sounds function will be a file with .csv (Comma-Separated Values) extension. To visualize the data, Microsoft Excel 2013 processed the .csv file into a graphic for every index (AEI, BIO, H, and NDSI) in each ecosystem.
Figure 2. AEI in each ecosystem

Figure 3. BIO in each ecosystem

Figure 4. H in each ecosystem

Figure 5. Point of recording sites in several types of ecosystem.

Information:
- Red line: Index values in plantation forest ecosystem
- Blue line: Index values in lowland forest ecosystem
- Grey line: Index values in coastal forest ecosystem
3. Result and Discussion
The results showed that the indexes can be used as a tool to predict biodiversity in an ecosystem. The AEI in the Plantation Ecosystem had range of 0.02 to 0.12 indicating the spectrum at each frequency range was equally strong. AEI also indicates that there is a frequency range dominance in Coastal Forest Ecosystem. H in the Lowland Forest Ecosystem had range of 0.74 to 0.89 and tends to fluctuate at any given time, indicating that animals in the ecosystem have a schedule of occurrences. NDSI on the Coastal Forest Ecosystem had a wide range between -0.38 to 0.54 indicating that the sound source varies. BIO monitored the timing of dawn and dusk singing of each ecosystem.

AEI and BIO, can visualize the biodiversity in an ecosystem well. H and NDSI seems to show anomaly data. H, theoretically, will increase proportional with the biological diversity in an ecosystem. H in Plantation Forest Ecosystem was the highest than Lowland Forest Ecosystem and Coastal Forest Ecosystem. Theoretically, biological diversity in Plantation is not bigger than Lowland Forest Ecosystem, so this result seems anomaly. It happens because of Shannon’s Index, which the BIO calculation based, have a character proportional to probabilities. Another anomaly data, NDSI result which are zero-values and negative-values. Theoretically, the zero-value of NDSI indicate that biophonies proportional with anthroponies and negative-value of NDSI indicate that biophonies weaker with anthroponies. Instead of that theory, zero-values of NDSI happened because of raining when the recording time, and negative-values of NDSI in Coastal Forest Ecosystem happened because of sounds of waves.

4. Conclusion
Those indices are interrelated and need to be interpreted simultaneously, to obtain a more comprehensive interpretation result. In addition to biophonies and anthroponies, the index can also indicate the presence of geophonies. Although the index may describe biodiversity and landscape at the location of the data collection, it is preferable if the description of data collection and voice identification could be done.

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