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Ecological Impact Assessment Framework for areas affected by Natural Disasters

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ABSTRACT

The forest's biodiversity consists of relations between trees, animals, the environment, and surrounding communities. Their existence required a certain balance both in number and composition. The diversity of the element itself creates a chain that connects each of the living things. Consistently, those mutual relationships are sometimes disturbed by pressures, whether man-made pressures or natural pressures. As a consequence of that event, the biodiversity loses its balance and becomes vulnerable to disaster. The fact that forest fire cases damage every living thing in the forest is becoming a massive issue in forest management. In some instances, the balance of forest biodiversity assembles an ecological resilience essential to the forest condition in combating disturbance. This paper reviews the biodiversity elements and their relationship to the extent to which elements will support ecological resilience. This is a review of 58 studies related to biodiversity balance and ecological resilience. The review discovered evidence that biodiversity components are connected and support each other. However, not every relation contributes to ecological resilience. As a result, we assess several biodiversity elements that might be useful in supporting ecological resilience, which are tree, environment, animal, and community. We also provide 2 case examples case to get the value of some biodiversity elements using a deep learning method.

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CCS CONCEPTS

• :; • **Computing methodologies** → Artificial intelligence; Computer vision; Computer vision tasks; Biometrics;

KEYWORDS

biodiversity, ecological resilience, forest fire, forest management, deep learning

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1 INTRODUCTION

The connection between forest fire and ecological resilience has been known for a long time. The fact that forest fire damage every living thing in the forest becoming a huge issue in forest management. Besides, forest area has their own biodiversity composition Certain composition of biodiversity elements will create an amount of resilience that will support a forest and faster its recovery. Ecological resilience itself is a systematic impact of animals, trees, the environment, and community mutual activities. The more those variables effortlessly return to the initial condition, the higher of resilience index they have [1], [2].

This paper relates to SILVANUS Project through European Commission Funding on the Horizon 2020. The project aims to develop an integrated technology and information platform to support the preparedness, response, and recovery phase of the wildfire management cycle and increase human, environmental, and economic resilience to wildfires. One of the project works is reviewing the ecological resilience programme to evaluate the program's impact on biodiversity. Biodiversity, a contraction of biological diversity, has several definitions. Biodiversity is biotic (species, genetic, and ecosystem diversity) [3–6] and abiotic components (landscape features, drainage systems, and climate) of ecosystems [4]. It defines as a forest ecosystem consisting of composition, structure, and function [3], [7], [8]. Reference [3] defines the biodiversity variable at four organization levels (regional landscape, community-ecosystem, population-species, and genetic). Every organization consists of several indicators grouped into composition, structure, and function [5], [9–11]. The other literature mentions species distribution [12], [13], [14] Structure points to the spatial array of diverse ecosystem components such as tree structure or tree spacing, and function refers to all ecological processes [7].

On the other hand, the biodiversity that live in the forest works in a certain system. Furthermore, its interaction relates to ecological resilience. Ecological resilience is the capacity of a system to absorb stress or disturbance and recover its composition, structure, and function [15–18]. Several stresses affecting biotic and abiotic elements in the forest are fire, drought, and insects [19–21].

Ecological resilience consists of several concerns, which are tree, environment, animal, and community. The first concern is the tree. Tree resilience indicator is forest structure. Forest structure consists of tree density [22], [23], [5], [7], [19], stand density [14], [15], Diameter at Breast Height (DBH) [19], [24–26], tree population [23], [24], [27], tree age [28], [5], [24], and tree height [5], [7], [24], [26]. Other indicators are tree mortality [29], [19], [25], non-tree vegetation [27], forest ecosystem type [21], [27], [30]. Reference [31] mentioned leaf model and canopy model as indicator. The second concern is the environment. The environment indicators are soils [26], [27], [30],[32]. Another reference [26] mentions topography, wind speed, snow load, lightning, and anthropogenic activity as environmental indicators as well. Reference [33], [34] also implied about wind as influence of ecological resilience. Other indicators are temperature [35], [36] and precipitation [37] in the forest area. The third is animals, where population becomes one of the ecological resilience indicators [27], [38], [38]. Although it is not mentioned in the reference [41], [42], it implies a biodiversity indicator which is species (both animal and tree) richness. Beside animal richness, animal population also have bigger role in increasing the higher resilience index in tree variables [10]. The fourth is the community [43], [44]. In identifying the community, several variables need to be considered, including the level of infrastructure development, and mobilization when forest fires occur [45], [46] . The following variable is government policy which is important to forest protection (also fire protection of forests) if it is implemented comprehensively [47–49]. The next variable is community empowerment [50], [51]. This variable is essential for the forest fire mitigation strategy by increasing public awareness and its role in fire and land prevention [50], [52]. The last component that needs to be considered is a livelihood [53]. It is related to forest conservation programs that should be linear with the community's needs and protect biodiversity as well [54].

Ecological aspects affect forest management; thus, calculating and estimating biodiversity becomes a tool for developing management strategies. The biodiversity reflects the forest's variability. The number of each species and its richness in a forest indicates whether an improvement occurred during forest monitoring or not [55].

2 METHODS

This research employs a literature review of papers related to biodiversity and ecological resilience. Keywords "biodiversity" and "ecological resilience" were used to search the papers. Sorted from 241 papers published from 1973 to 2022, we found 58 related papers. However, we did not cite all of those papers in this paper. An in-depth analysis was conducted to form the most suitable biodiversity measurement that influences ecological resilience. The analysis started with classifying the biodiversity component into tree, environment, animal, and community papers. The biodiversity components selection process was choosing which part of the biodiversity supports the ecological resilience as a whole.

Secondly, we propose a computer vision based integrated mobile application to capture some of biodiversity. We utilize a VGG 16 architecture to model the variation of the leaf and butterfly as a proof of concept. Some of the biodiversity are correlated with visual clues, while some parameters might not be able to detect. We also consider crowd sourcing data to collect biodiversity by using mobile application to improve community engagement in monitoring the forest and environment in general.

The steps in this research are: 1) Defining Biodiversity and Ecological Resilience, 2) Selecting biodiversity variables with visual cues, 3) Define dataset, 4) Training and evaluating the deep learning framework for the model, 5) Implementing a model mobile application for the citizen to capture the picture from the forest.

Currently, we use the publicly available datasets to train our deep learning framework. They are leaf dataset [56] and butterfly dataset [57]. The detail of the datasets is explained in Tb1.

As we can see in table 1, the number training size in butterfly much more than leaf dataset. Due to the lack of dataset size, the testing and validation data for leaf dataset are 25% for each class. It will lead to a risk of low performance classification. Butterfly dataset on the other side, has enough data size and therefore we can expect well performance model. Moreover, the number of testing and validation size compared to the training size are very small and it will help the model to build a good pattern to represent the variation of input.

In this research, we propose a transfer learning of VGG 16 [58]. Head replacement carried to fit to the problem with the number of class target. We retrain all layer with the dataset for fine tuning. The best model for each dataset is saved and implemented in the server

Table 1: ***Dataset Composition***

Dataset	Class	Image Size	Training Size	Validation	Testing
Butterfly	75	224 x 224 pixel	9.285	375	375
Leaf	40	720 x 960 pixel	178	133	133

to provide recognition service for the mobile application. Prior to the implementation to provides service to mobile application an evaluation carried out to the models. Researchers adopt accuracy, precision, recall and F1-score to evaluate the performance of the classifier. In current state of the research, we provide a prototype of end user mobile application. The mobile application will consume the web service for butterfly and tree recognition based on its leaf.

3 RESULT

Forest area tends to have a rich biodiversity, consisting of the tree, animal, and the environment. Each individual plays an important role in the forest ecosystem. Their activities form a forest system in a certain way. For instance, the food chain and individual habits form their mechanism. However, not all of the element's existence has a good impact on supporting forest sustainability. Some of them reduce the stability of the forest, resulting in resilience loss.

3.1 Biodiversity Element

Key elements of environment are abiotic, biotic, and culture. The abiotic environment elements that give important value to the biodiversity are soil, climate, weather, temperature, annual precipitation and wind condition. The biotic environment consists of tree, animal and community. Tree is an important element of the forest which could increase forest resilience if fires occur in the future [59]. On the other hand, tree is beneficial as carbon storage and species habitat [60]. Furthermore, the sustainability of a forest requires tree support. There are several indicators of tree to increase ecological resilience from fires. The indicators are tree density, tree population, non-tree vegetation, mortality rate/burned tree, and forest type. The biotic environment consist of tree, animal and community. Tree is an important element of the forest which could increase forest resilience if fires occur in the future [59]. On the other hand, tree is beneficial as carbon storage and species habitat [60]. Furthermore, the sustainability of a forest requires tree support. There are several indicators of tree to increase ecological resilience from fires. The indicators are tree density, tree population, non-tree vegetation, mortality rate/burned tree, and forest type.

Forest becomes the habitat of millions of species of animals. They eat, sleep, and basically living in the forest forming its own ecosystem. That is why the ecological structure and dynamic basically ruled by animals and plants [10]. When the forest is structed by the wildfire, the disturbance of the forest is getting intense. Damaging the ecosystem, including small to large animals. The important elements from animal are animal richness, animal population and the mortality rate.

Community involvement is vital to maintain the continuity of production and productivity of an ecosystem in meeting the needs of active communities in the system. A researcher stated that the community plays an essential role in maintaining the survival of an ecosystem to achieve ecological resilience. A community with ecological resilience shows a strong attachment (cohesiveness) in disturbance conditions but can absorb the disturbance and adjust after the trouble is gone [61]. Based on literature studies related to the community's position in supporting ecological resilience, four supporting factors need to be identified to determine the extent to which the community can help achieve ecological resilience. The four factors are infrastructure development, government policies, community empowerment, and livelihoods. Fig 1 illustrates the biodiversity components that contribute to ecological resilience as the first result of this study.

3.2 Biodiversity Component with visual Clue

As seen in figure 1, there are some biodiversity parameters. Some of the parameters are visually observed such as diversity, density and population of the tree as well as animal. Tree population can be estimated by using satellite or aerial images. While the tree and animal diversity can be collected by ground photo. In this research, crowdsourcing photo from the ground is collected through mobile application. In this paper we focus on discussion of tree and butterfly species recognition through its pictures. More complex systems will be equipped with other classes of tree and animal.

There are six steps carried out in the application: 1) Capture the photo, 2) Record the geolocation, 3) Send the image into server, 4) Recognize the tree species or the butterfly species, 5) Response the mobile application about the tree or butterfly species and ask for user feedback, and 6) Record as the tree and animal diversity in the certain location (geotagged).

3.3 Deep Learning Model

The application is designed to work on cloud server as the recognizing machine. No recognition ability designed to work on the edge application on the mobile devices. Mobile application takes a role of visual data capturing and user response as well as feedback. Publicly available dataset of leaf and butterfly are utilized to train and evaluate the performance of the classifier.

We adopt VGG 16 deep learning architectures by importing trained parameters in transfer learning techniques. Head replacements carried out to fit the number of class target, 40 for leaf and 75 for butterfly. To adapt the parameters for the current dataset, fully retraining carried out for all layers of the architectures. Figure 2 shows the architecture of VGG 16 adopted in this research and head replacement on the top of the fully connected layer.

Figure 3.a shows the training accuracy and training loss during the model development for butterfly species recognition. As we can see the accuracy was significantly improve bot training and validation in early training iteration (epoch). Validation accuracy however, saturated in early iteration at about 7th. Although training accuracy still keep improving (blue line), the validation accuracy

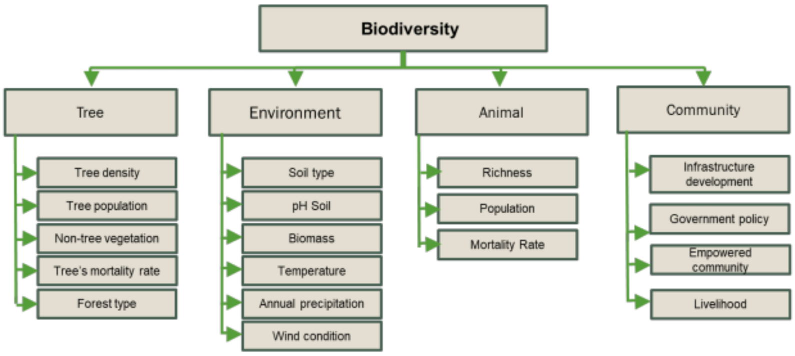


Figure 1: Biodiversity Component that Support Ecological Resilience

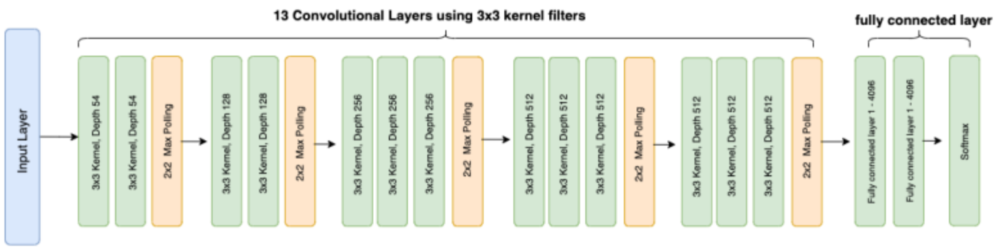
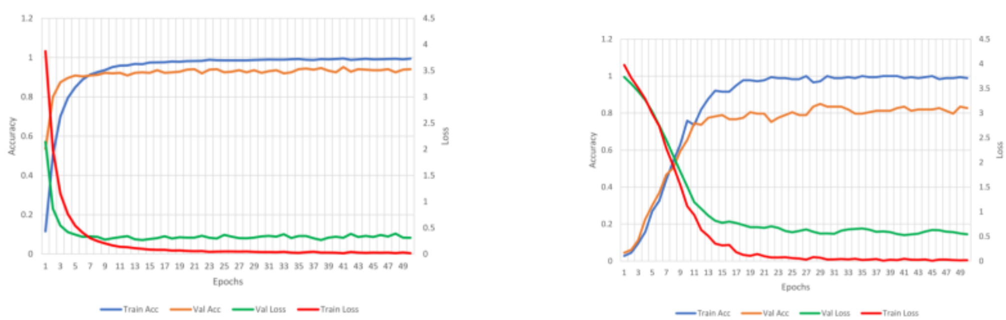


Figure 2: VGG 16 Architectures



a. Butterfly Dataset

b. Leaf Dataset

Figure 3: Training accuracy and loss, validation accuracy and loss

stays at about similar value with small fluctuation under the training accuracy. It is indicated that the classifier has achieved the best model in early stage of training.

Figure 3.b shows the training, validation accuracy and loss. The learning curve of the classifier shows the classifier performance speedy improved at the early training iteration. It was slowing down in about 15 epoch while the gap between validation and training become wider. It shows the classifier experience an overfitting. Best validation accuracy has achieved at 28th training epoch. The best achievement of the model for butterfly and leaf dataset can be seen in Table 2.

Table 2 shows the performance of the classifier in recognizing the species of butterfly and leaf. It shows that the classifier is working well for the butterfly dataset and far worst on the leaf dataset. The result is mainly caused by the composition of the dataset. To improve the performance of the leaf recognition, additional data need to be added to the dataset for better modeling of the classifier.

Table 2: *Classifier Performance for Each Dataset*

Dataset	Subset	Accuracy	Precision	Recall	f1-score
Butterfly	Testing	93.3%	94.2%	93.3%	93.1%
	Validation	94.1%	95.1%	94.1%	94.1%
Leaf	Testing	79.7%	81.1%	79.6%	77.8%
	Validation	82.7%	85.0%	82.5%	81.0%

Figure 4: Application Architectures and Mobile Application Interface

Another way to improve the performance is the data augmentation as reported in our previous paper [62].

Although the model for leaf recognition is not satisfying with 79,7% of accuracy, it is promising result. We believe additional data will help improving recognition rate. In the next step of the research, we will conduct field research to collect the samples and provide annotated dataset for various type of the forest tree and animal. Currently, we implement the model to provide web service to the prototype of mobile application for end user.

3.4 Mobile Application for Community Crowd Sourcing Biodiversity Data Collection

The mobile application take a role as the edge application to collect the visual data, returning classification result and gathering feedback. Citizen engagement will be the key success factor of data collection and therefore the mobile application will have many other interesting features for the community such as weather information, user guidance for echo tourism, maps and many more. Since this paper focus on the main function of the application as the visual data collector. Figure 4 shows the entire application architecture with the endpoint on user interface for user to capture the visual data, feedback and shows the class of the collected image. Integration with a machine learning server such as the one described in [63] would be also possible to automatically record the geolocation and aggregate the collected data.

4 CONCLUSIONS

Among all biodiversity components, several of them give an impact on the return of the ecological resilience. This study eliminates those components into definite categories: tree, environment, animal, and community. Tree density, population, mortality rate, and forest type have a beneficial impact on the forest's ecological resilience. On the other hand, environment components such as soil type, pH soil, biomass, temperature, annual precipitation, and wind condition also support biodiversity. As a member of the forest ecosystem, animals impact their richness, population, and mortality rate. The last variable whose activities influence ecological resilience is community. As local people who live near the forest or in the same territory, their livelihood, policy decisions, and built infrastructure affect the disturbance area positively or negatively.

In this paper we also identify some biodiversity component with visual clues. There are trees and some animal. We also identify image sources for examining biodiversity which are aerial photography, satellite images and ground image. We focus on ground images from community through mobile application. We provide a proof of concept, a VGG 16 based multiclass classifier for leaf and butterfly species recognition. According to our experiments, the size of dataset significantly affects the recognition rate and therefore we need more annotated dataset to ensure better classification quality. This research also provides a mobile application for community participation in crowd sourcing biodiversity evaluation for trees (with leaf image) and butterfly. We need to expand the dataset to various animals such as mammals, birds, insect and many more with enough number of samples. The fact that in one image it may contain more than one region of interest for example it bird, insect and leaf in the future beside image classification, we need segmentation task to tackle those problem.

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