# WP5: Promoting Asi@Connect-enabled Research and Education Collaboration for Societal Benefit

# Project: Extending Asian Soundscape Monitoring Network and Moving Towards Open Science Platform

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## Abstract

Soundscape reflects the dynamics of biological, ecological, environmental and societal systems of a landscape as well as the interactions between them. Through the long-term monitoring of soundscape, the impact and changes of the environment could be revealed even the organisms inside are not visible. Investigation of the temporal patterns of soundscape can provide insights into characteristics of primary acoustical events, and correlations of the driving forces of the changes. Analysis of acoustic signals patterns can also improve the deeper understanding of phenological patterns, species diversity, and ecosystem integrity. Previous studies have focused on ultrasonic bats, birds, calling insects, soniferous fishes, and marine mammals. From 2014, Academia Sinica and Taiwan Forestry Research Institute have collaborated with South-East Asia countries and established 9 soundscape monitoring sites in Malaysia, Taiwan, Thailand, and Vietnam. Current platform already collected approximate 10 TB raw data and provided basic functions on data management, query, listening, and visualization. New web portal designed by soundscape data workflow with extensive machine-learning supported analysis services will be released by the end of PM12. While extending the soundscape monitoring network in Asia, more user communities from partner countries will be engaged. Through planned training and dissemination events, the capacity to monitor the dynamics of the coupled natural-human system and to enhance the balance of biological diversity and environmental changes would be established. This collaboration will realize the first open science platform and applications on ecological and biodiversity soundscape monitoring in Asia.

With support of TEIN and APAN infrastructure, the soundscape monitoring network could further extend to global scale by integrating all Asia countries and related resources in Europe, America and Africa. All the data, tools, analysis facility, knowledge, soundscape monitoring protocols, and other resources would be freely shared freely to the education and academic communities worldwide. The platform which is built over the regional distributed computing infrastructure will continuously evolve and consolidate advanced analysis tools from user communities to provide innovative services.

# Introduction

## Importance of soundscape monitoring

The human population have increased dramatically over the last two centuries. Consequently, vast natural areas have been converted into human-managed landscapes to support people's high demands on natural resources. The global-scale consumption of natural resources has not only directly caused losses of species and associated ecological functions, but also led to degradation of environmental quality due to ecosystem collapse. Careful monitoring on biodiversity and ecosystem health at large spatio-temporal scales is necessary to mitigate impacts of human-induced environmental changes, including climate changes, hence, to secure human well-being.

Monitoring on ecosystem dynamics across large spatial and temporal scales is difficult due to the limitation of direct observation and field sampling. Soundscape is the total sound composed of environmental (wind, rain, thunder, etc.), biological (animal calls, songs, etc.), and anthropogenic sources in a location at a given period of time. With analog to imagery remote sensing, passive acoustic sensing / monitoring can help document soundscape for studying the changes of soundscape due to natural processes and human activities. In recent years, abundant researches have revealed that soundscape monitoring is an important measure to study the global changes in biodiversity, ecosystem functions, and the health of environment and human being. Therefore, establishing a global network for monitoring the soundscape of the earth is one the essential task to reveal and resolve the urgent issues in global changes by raising the public awareness and informing decision makers.

Soundscape reflects the dynamics of biological, social, and physical systems of a landscape (Gage and Axel, 2014), as well as the interactions among them. Through the long-term monitoring of soundscape, the impact and changes of the terrestrial and aquatic environments could be revealed even the organisms inside are not visible. Previous studies have focused on ultrasonic bats, birds, calling insects, soniferous fishes, and marine mammals. Investigation of the temporal patterns of soundscape can provide insights into characteristics of primary acoustical events, and correlations of the driving forces of the changes. Analysis of acoustic signals patterns can also improve the deeper understanding of phenological patterns, species diversity (Sueur et al., 2008), and ecosystem integrity (Qi et al., 2008) in both aquatic (Lin et al. 2013; 2015a, b) and terrestrial ecosystems (Sueur et al., 2008).

## Existing research

To establish the long-term soundscape monitoring network in Asia, Taiwan Forestry Research Institute and the Academia Sinica Grid Computing Center (ASGC) together initiated the Asian Soundscape Monitoring Network and hosting a training workshop in November, 2014 in Taiwan. Twenty seven participants from Malaysia (2), Philippines (2), Taiwan (19), Thailand (3), and

Vietnam (1) joined this workshop. The consensus was reached on collaboration of monitoring soundscape in Asia and open data policy to share the soundscape data with public to promote soundscape research and conservation, thus the Asian Soundscape Open Archive (http://soundscape.twgrid.org) was established.

## Asian Soundscape Monitoring Network and Open Archive

Since 2014 this open archive has accumulated more than 160,000 files of soundscape recordings (each file is five minutes long) and has exceeded 8.5 TB from nine monitoring sites distributed in Malaysia, Taiwan, Thailand, and Vietnam (Figure 1 and Table 1). Being aware of the limitation of current infrastructure to archive the long-term soundscape big data for continuing and expanding this monitoring activity in Asian region, several challenges in ICT support need to be resolved to make soundscape monitoring sustainable and scalable.



Figure 1. Asian Soundscape Open Archive

Table 1. Detailed information on the soundscape monitoring sites of Asian Soundscape

| Country | Organization | Site | Start and End Date | Number of Files | Approx. Size of the Accumulated Original Soundscape Archive |
|---------|-------------|------|-------------------|-----------------|-----------------------------------------------------------|
| Malaysia | Malaysia: Forest Research Institute of Malaysia<br><br>Taiwan: Taiwan Forestry Research Institute | Pasoh Research Forest | 2015-03-13 to 2016-06-18 (stopped) | 20,222 | 1.051 TB |
| Taiwan | Taiwan Forestry Research Institute | Lienhuachih Research Center, Yuchih, Nantou County | 2014-10-29 to 2016-12-14 (continued) | 37,176 | 1.93 TB |
| Taiwan | Taiwan Forestry Research Institute | Mt. Triangle, Sanyi, Miaoli County | 2015-01-24 to 2016-12-03 (continued) | 31,245 | 1.62 TB |
| Taiwan | Taiwan Forestry Research Institute & Taiwan Forestry Bureau | Mt. Taiping, Yilan County | 2015-01-29 to 2016-12-24 (continued) | 32,266 | 1.68 TB |
| Taiwan | Research Center for Information Technology Innovation & Taipei Guandu Nature Park | Guandu Nature Park, Taipei City | 2016-04-29 to 2016-10-10 (continued) | 8,830 | 0.46 TB |
| Taiwan | Research Center for Information Technology Innovation & Taiwan Environmental Information Association | Nature Valley, Hsinchu County | 2016-07-28 to 2016-09-23 (continued) | 2,345 | 0.12 TB |
| Taiwan | Research Center for Information Technology Innovation & Taiwan Forestry Bureau | Shuang-liu Forest Recreation Area, Pingtong County | 2016-09-01to 2016-10-17 (continued) | 2,201 | 0.11 TB |

| Thailand | Thailand: Center of Excellence for Ecoinformatics, School of Science, Walailak University & Khao Nan National Park<br><br>Taiwan: Taiwan Forestry Research Institute | Parah forest of Huai Lek HQ, Khao Nan National Park, Nakhon Si Thammarat | 2014-12-09 to 2015-10-14 (stopped) | 12,855 | 0.67 TB |
| --- | --- | --- | --- | --- | --- |
| Vietnam | Vietnam: Department of Zoology, Southern Institute of Ecology, Vietnam Academy of Science and Technology<br><br>Taiwan: Taiwan Forestry Research Institute | Natural broad-leaved forest in Bidoup-Nui Ba National Park, Dalat | 2015-01-23 to 2016-01-11 (stopped) | 16,771 | 0.87 TB |

Researches in aquatic and ultrasonic soundscapes

In recent years, monitoring of marine soundscape has been initiated in Japan, Hong Kong, and Taiwan to study the behavioral response of endangered mammals in coastal waters and river estuaries to the change of soundscape. Marine soundscape represents the essential resource for the communication and orientation of marine mammals. Marine mammals not only rely on sound for communication and orientation, they can also eavesdrop the fish chorus to increase their foraging efficiency (Guan et al. 2015). However, noises produced by shipping activities and offshore energy developments may impact the physiology and behavior of marine mammals (Weigart 2007, Southall et al. 2007). The long-term alteration of marine soundscape may also increase their chronic stress and reduce the fitness of these endangered animals (Rolland et al. 2012). Therefore, the monitoring of underwater noise and marine soundscape has become an important task for the conservation management of marine environment.

Monitoring the ultrasonic soundscape will also help study the bat diversity and ecosystem functions because bats provide several crucial ecosystem services, including pollination for tropical fruits and removal of pests, etc. Recent ongoing establishment of regional-level call libraries of bats in some countries in Southeast Asia, e.g. Malaysia and Vietnam, indicates that applying acoustic techniques to study bat biodiversity and ecology is of great interest.

## Challenges

Long-term monitoring of soundscape will generate ever-increasingly huge volume of sound data. Based on current protocol we adopted (collecting 5 minutes recording for every half hour),

around 1TB data will be collected for a terrestrial soundscape recorder in a year. Currently, there are several independent soundscape monitoring programs in North and South Americas as well as in Europe and UK. To facilitate sharing, exploring, and reusing the soundscape big data from the monitoring networks for open science and social benefits, apparently, there is an urgent need in strong support of information and communication technology (ICT) to help integrate and scale out the collective efforts at global scale. Data management and analysis based on persistent storage and high-performance distributed computation are necessary for establishing global soundscape monitoring network in near future.

## Scale-out

To scale out the existing soundscape researches and network in Asia, we propose this project to establish an open platform based on persistent storage and distributed computing resources supported by TEIN and APAN infrastructure, as well as to expand the monitoring network into aquatic and ultrasonic soundscape. Moving this whole system towards an open science platform is a defined long-term goal.

### Persistent storage and distributed computing

The soundscape research network is composed of the service and application platform integrated with the distributed computing infrastructure (DCI; Figure 2). Based on the requirements identified from the Asia Soundscape Monitoring Network, all the data management and service components as well as the analysis and knowledge services would be provided by the federation of distributed clouds in participating institutes. Taking into consideration of data-oriented strategy and systematic scalability and efficiency, distributed computing infrastructure is a natural and most viable solution to support the data, analysis and collaboration requirements from distributed soundscape monitoring sites and scholars in many Asian countries and the world. In addition to the improvements of overall system performance, scalability and reliability, DCI could also enhance application portability, flexibility and data integrity if we have right implementation of computing models over heterogeneous resources (e.g, through container or virtual machine technologies). Furthermore, access latency to the services could be reduced by arranging resources (data and analysis services) close to the users. The soundscape monitoring network is an scalable open platform which integrates the DCI, sensor network, persistent open archive, machine learning enabled analysis, case studies and knowledge base over the TEIN backbone.

# Open Science Platform for Soundscape Research Network

**User Communities**

**Training & Dissemination**

**Soundscape Data Acquisition**

**Visualization Services**

**Case Studies**

**Data Services**  **Analysis Services**

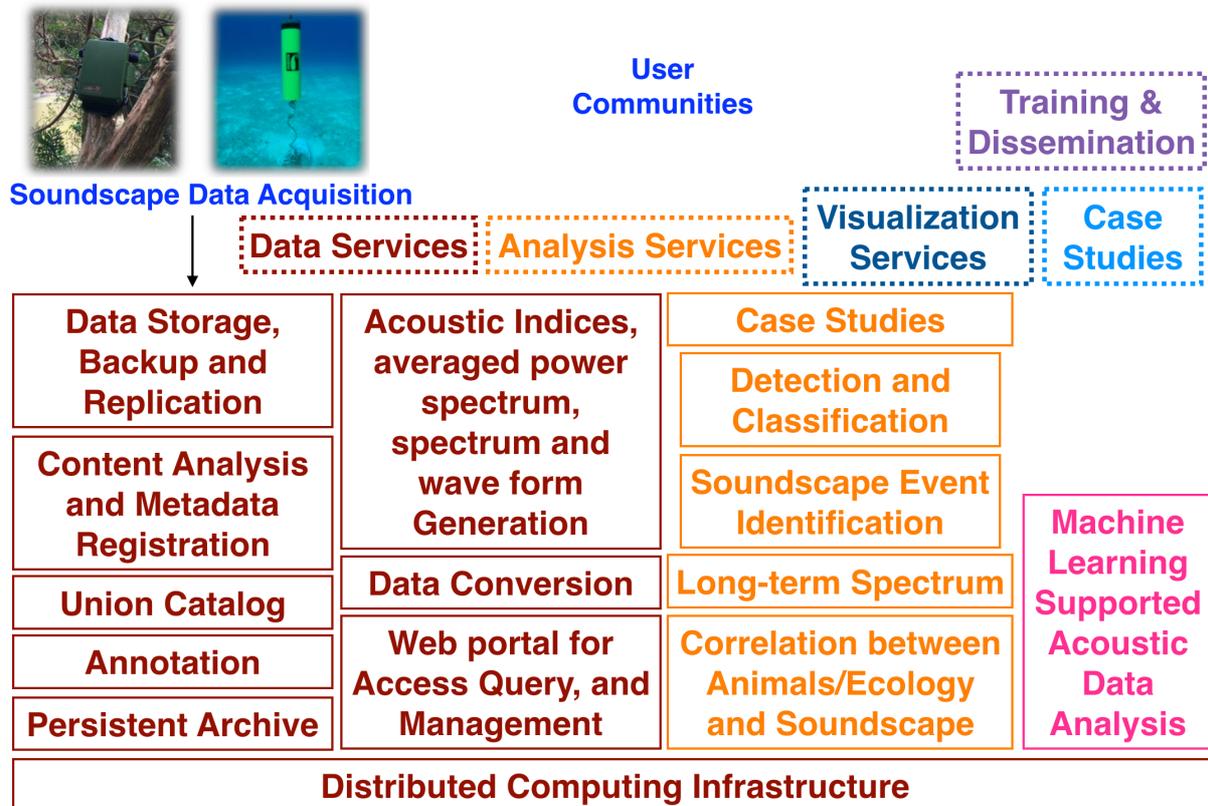| Data Storage, Backup and Replication | Acoustic Indices, averaged power spectrum, spectrum and wave form Generation | Case Studies | |
|---|---|---|---|
| Content Analysis and Metadata Registration | | Detection and Classification | |
| | | Soundscape Event Identification | Machine Learning Supported Acoustic Data Analysis |
| Union Catalog | Data Conversion | Long-term Spectrum | |
| Annotation | Web portal for Access Query, and Management | Correlation between Animals/Ecology and Soundscape | |
| Persistent Archive | | | |

**Distributed Computing Infrastructure**

Figure 2. Data and analysis services based on distributed computing infrastructure

## Expand the monitoring network

Current soundscape monitoring network only includes the audible soundscape in the terrestrial environment in four Asian countries. To extend the monitoring network into different ecosystems and different frequency range for more comprehensive understanding of our environment, we propose to establish aquatic and ultrasonic soundscape monitoring network incorporated into the distributed computing infrastructure. This expansion will foster the research and conservation of soundscape in Asia.

# Set of objectives

- Establishing soundscape collaboration network by integrating the data management and analysis platform over DCI.
- Enhancing the capacity of ecology and biodiversity monitoring by soundscape for both the country-level and Asia regional level.
- Supporting case studies: Providing services of data management and data analysis by integrating tools and methods developed by other-sub projects into the DCI.
- Providing data, analysis and case study services to the public.
- Investigating the temporal and spatial change of aquatic and ultrasonic soundscape.

- Facilitating the monitoring of aquatic biodiversity and ecosystem through the soundscape information.
- Developing a cost-effective acoustic tool for monitoring bat diversity in response to environment changes in the Southeast Asian tropics.

# Expected outcome

- This collaboration will realize the first open science platform and applications on ecological and biodiversity monitoring in Asia. With support of TEIN and APAN infrastructure, the soundscape monitoring network could further extend to global scale by integrating all Asia countries and related resources in Europe, America and Africa. All the data, analysis tools and protocols, knowledge, and other resources would be shared freely to the education and academic communities worldwide. The platform built over the regional distributed computing infrastructure will continuously evolve and consolidate advanced analysis tools from user communities to provide innovative services.

- While extending the soundscape monitoring network, the user communities of new partner countries will be engaged. Through the planned training and workshop events, the capacity to monitor the dynamics of the coupled natural-human system and enhance the balance of biological diversity and environmental changes would be built up. Case studies from partners are also encouraged to broaden the soundscape applications and integration with other disciplines. Novel analysis and applications will be developed accordingly and improve the collaboration platform.

- The efforts on the monitoring of aquatic soundscape will establish a first open database of aquatic soundscape recordings in the Southeast Asia region. We will focus on the spatial and temporal changes of marine soundscape in river estuaries and coral reefs. Through the long-term monitoring of aquatic soundscape, it is expected to understand: (1) the relationship between aquatic biodiversity and soundscape complexity, and (2) the impact of soundscape change on the community of aquatic calling animals.

- For monitoring ultrasonic soundscape in the Southeast Asia, we expect to devise the first internet-based bat acoustic tool, including an automatic bat call classifier and an index calculator. In the short term, the expected tool will facilitate the development of management of natural resources that are associated with bats in the selected countries, Vietnam and Malaysia, by holding workshops and establishing national-level monitoring network through integration of the tools with existing research and education networks. In the long term, establishment of the tools could bring broader impacts on bat conservation and research in the region by promoting the soundscape monitoring network to the rest of Southeast Asia's countries.

## Synopsis program

### Development of DCI-based soundscape open archive

To create a scalable and sustainable open science platform for the soundscape monitoring network in Asia, we will adopt open source tools and the distributed computing infrastructure supported by TEIN and APAN partners. This open platform will integrate more comprehensive functions in data management for documenting detailed metadata, file format conversion, soundscape index calculation, machine-learning aided soundscape classification, and visualization of long-term soundscape. All these essential functions will facilitate managing, discovering, exploring, and reusing the soundscape big data using distributed computing and persistent storage resources, which is not achievable by a single country.

### Integration of the machine learning and soundscape research network

In this project, we will support researchers and stakeholders in Asia to establish a long-term soundscape monitoring network. However, analysis of acoustic big data remains a challenging task for ecologists and environmental researchers. To facilitate the data analysis without sufficient labeling data, we developed the following three tools for unsupervised classification and data visualization of soundscape recordings: (1) long-term spectrogram viewer, (2) biological chorus detector, and (3) soundscape event classifier.

The long-term spectrogram viewer helps users to visualize weeks or months of recordings. Users can search for transient noise and biological chorus from the long-term spectrogram. Users can also employ the statistical analysis to measure the temporal and spatial dynamics of soundscape, therefore, the correlations between soundscape complexity and biodiversity can be measured. The biological chorus detector can automatically recognize the periodical chorus without any sound template based on the technique of unsupervised non-negative matrix factorization. Users can use this algorithm to enhance the signal quality of biological chorus and study the spatial and temporal change of biological chorus. After we separate the biological chorus and non-biological noise, we can identify various events by using the soundscape event classifier. Therefore, even though users do not have sufficient label data to recognize different sound sources, but our toolbox can still help users to effectively investigate the compositional change of calling animals through soundscape information. We will conduct several training workshops and open this analysis toolbox. We will also integrate the toolbox with open science platform of soundscape monitoring to provide interested researcher and stakeholders for different option of data analysis. All the analysis results will be published on the cloud data center in order to encourage the collaborations between different researchers and stakeholders.

### Extending the monitoring network into aquatic and ultrasonic soundscape

For establishing a prototype to monitoring aquatic soundscape in South-East Asia, we will try to deploy at least one set of submersible sound recorder (two sets of sensors could be possible if sufficient funding support is available), such as SoundTrap 300 recorder, in one selected partner country. The submersible recorder can be scheduled in duty cycle and store sound

recordings in internal hard disks or memory cards. Although they represent the offline system, but they are relative low-cost when comparing to those online systems which can be operated in an aquatic environment. We will collaborate with researchers and stakeholders in Southeast Asia and train their staffs to deploy and retrieve the submersible recorder in different environments. However, we will primarily focus on river estuaries and coral reefs because they represent the biodiversity hotspot of marine environment and also the important region of human activities, such as fishing, tourism, and industrial developments.

For monitoring bat biodiversity and ultrasonic soundscape, we will develop an online tool providing cloud services of bat call identification and sound diversity index calculation for selected countries in Southeast Asia. We will develop an automatic call classifier based on existing call libraries and reference calls collected from fieldwork of this project using statistical models (e.g. random decision forests) and machine learning. Passive ultrasound recorders will be set up with weather meters simultaneously at selected sites in Malaysia and Vietnam to monitor bat activity and weather conditions for an 18-month period. To validate the effectiveness of current diversity and sound indices for monitoring bats acoustically, associations among indices, variations of call diversity, and weather condition will be estimated. The call classifier and index calculator will be coded with free open resources (e.g. R and Python languages) and implanted in an online tool with national research and education networks and TEIN in the two selected countries. In addition, an acoustic workshop for local researchers, students, stuff from NGOs, and management agencies for each country will be held in the 2nd fascial year to build up the carrying capacity of bat acoustic monitoring.

## Target Participants

| Country | Organization | Contact |
|---------|-------------|---------|
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# Other collaborations or related awarded projects or grants by other funding agencies

- Taiwan Forestry Research Institute, Council of Agriculture, Taiwan supports the collaboration on monitoring the forest soundscape in Malaysia, Thailand, and Vietnam, as well as maintains the current Asian Soundscape Open Archive.
- Academia Sinica Grid Computing Centre, Taiwan hosts the the Asian Soundscape Open Archive and provides ICT supports for running the service.
- Research Center for Information Technology Innovation, Academia Sinica hosts the project "Investigation on the interactions between ecological environment, wildlife animals, and human activities using soundscape information" supported by Ministry of Science and Technology, Taiwan.
- Research Center for Information Technology Innovation, Academia Sinica hosts the project "Bio-acoustic signal enhancement," supported by iMediPlus Inc.
- Biodiversity Research Center, Academia Sinica, Taiwan supports a project for establishing call library and acoustic monitoring protocol for Vietnam's bats. The Malaysia part is sponsored to Dr. Faisal Ali by internal funding from his university under a collaboration with Biodiversity Research Center, Academia Sinica.

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# Supplement to the Project
# Extending Asian Soundscape Monitoring Network and Moving Towards Open Science Platform

## Introduction

Soundscape provides a framework to describe, compare and analyze acoustic information, covering all the frequencies that are dominant during certain time interval, from many sites and many animal taxa simultaneously. Macro or community acoustics are the focus of soundscape ecology which is to investigate the composition of all sounds at a location including biological, geological, anthropogenic sound or noise in the environment.

Soundscapes represent the heritage of our planet's acoustic biodiversity. Recordings made today probably preserve the only evidence we have of ecosystems that may vanish in the future. Acoustic methods offer a cost-effective way to autonomously collect large amounts of data, providing continuous, simultaneous and permanent records of vocal animals that can be reanalyzed and further explored to answer new questions.[1]

The vision of this project is to facilitate ecological sustainability by enhancing our understandings of interactions between biological and anthropogenic factors through soundscape. This is the first organized efforts to build up soundscape collaboration network covering tropical and sub-tropical regions in Asia. In this project, we extend the soundscape to ultrasonic range and include bat into this study. The first Asia regional soundscape monitoring network is composed by sites in at least 5 countries and collecting terrestrial, aquatic or ultrasonic data. New soundscape site is able to join and share data through the regional open collaboration platform. Scientists from Asia countries could, for example, develop data-oriented analysis models and services to identify anthropogenic and biological processes and spectral and temporal patterns in the soundscape as well as investigate how disturbance alters patterns and processes across scales.

## Goal and Objectives

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[1] Aide, T.M., Corrada-Bravo, C., Campos-Cerqueira, M., Milan, C., Vega, G., Alvarez, R., 2013. Real-time bioacoustics monitoring and automated species identification. Peer J. 1, e103

The primary goal of this project is building capacity to understand the ecological changes of anthropogenic and environmental impacts by soundscape network in Asia and facilitate innovative applications on soundscape by sharing of knowledge and resources, and by establishing collaborative communities. Through this collaboration, we will be able to evaluate the dynamics of biodiversity on soundscape and study the interactions between wildlife, habitat and human activities. Target user groups are communities of science, ICT infrastructure, big data analysis, ecology, sustainability, environmental changes, as well as related organizations and agencies, practitioner and policy makers. Accordingly, objectives are core tasks to accomplish the highlighted goal summarized below.

1. Establish soundscape collaboration network by federating distributed data, resource, analysis facility and domain experts over distributed computing infrastructure: A scalable and productive architecture consists of monitoring sites, distributed storage and management facility, analysis facility, application portal and distributed cloud infrastructure will be built up. This collaboration is conducted by scientists of disciplines from biology, data science, infrastructure and ICT, and physics, and working together with local communities in Asia countries.

2. Enhance the capacity of ecology and biodiversity monitoring by soundscape for both country-level and Asia regional level: The project integrates terrestrial, aquatic and ultrasonic soundscape to expand the monitoring capability of diverse ecosystems and broader frequency ranges. Local communities of different roles are trained and supported to operate and make use of the soundscape facilities, for example, to collect, process, explore, analyze and visualize soundscape data. Seven new soundscape monitoring sites of the three types in four partner countries will be setup. Analysis services and applications will be integrated and developed according to the users' needs.

3. Buildup Soundscape Open Collaboration Platform to share the knowledge, data, tools, services and resources wrapped up from case studies: In addition to providing data sharing and management (from collection, access, query, preservation, to analysis and value-added application support), the open collaboration platform shares all the resources the project

acquired and generated from constant monitoring and case studies. The open collaboration platform will keep evolving to integrate innovative applications from user communities, more case studies and extended collaboration driven by scientific studies and sustainable development. More than 400K minutes soundscape recordings at 8 monitoring sites in 5 Asia countries will be open access.

4. Develop and provide data-oriented machine learning enabled analysis facility on soundscape: The principle focus is to evaluate the dynamics of soundscape and biodiversity and to study the interactions between wildlife, habitat and human activities. Innovative methods and services such as to identify temporal and spatial changes of biodiversity, source separation, detection and classification of specific targets, long-term spectrogram processing and flexible visualization model will be developed.

5. Dissemination and Outreach: To support user engagement and broaden substantial impacts of the project, several trainings on soundscape data collection and analysis at partner countries will be conducted. Outcomes of the initiative will be disseminated and exploited through communication and transfer to partners by the open collaboration platform. Scientific publications and conference posters, presentations are major means of dissemination. This activity will ensure the quality of project website which will host project reports, outcomes and services, schedules of events, and links to partners. The initiative will also expand collaborations with soundscape, ecology and biodiversity, and sustainability development related international projects.

**Deliverables**

1. [PM3] First release of the project website and a web portal to upload, access, and visualize acoustic recordings and field photos of study sites is available.
2. [PM9] Machine learning enabled analysis of soundscape information, including visualization of long duration recordings, separation and cluster of different acoustic signals as well as for quantification of acoustic diversity, is integrated with the web portal.

3. [PM21] A series of Masterclass and trainings for soundscape data collection, analysis, and applications will be carried out. Masterclass will be collocated with TEIN/APAN meetings or ISGC Conference twice a year. Trainings are carried out in three groups for terrestrial, aquatic and ultrasound soundscapes, either in the Masterclass or independently. Target participants are researchers and students of four South East Asian partner countries.

4. [PM21] Journal and conference articles about the case studies on marine biodiversity, terrestrial forest, and cave ecosystem on the basis of soundscape as well as the open collaboration platform will be submitted.

5. [PM22] A conference on soundscape is held by end of this project. Apart from the promotion of project results and achievements, the focus is also to communicate with broader potential users and policy makers and to expand the collaborations in the long run.

**Milestones**

1. [PM3 and PM9] Convene training workshops on soundscape data collection, on terrestrial, aquatic and ultrasonic soundscape respectively in at least two partner countries.

2. [PM3] Launch the open data of Asian soundscape

3. [PM6] Start soundscape data collection from new aquatic and ultrasonic sites in at least one partner country

4. [PM12] Publish the open toolbox for visualizing and analyzing soundscape information

5. [PM15] Demonstrate case studies on the basis of Asian soundscape

6. [PM15 and PM20] Convene training workshops on soundscape data analysis and applications, on terrestrial, aquatic and ultrasonic soundscape respectively in at least two partner countries.

7. [PM22] Submit the final report

**Visibility and Communication**

In addition to publish project information and accomplishments to the project website, academic conferences and publications, we will also deliver the breakthrough, applications and stories of this collaboration through various media channels including social media and internet communities. Information campaign to raise the awareness of ecological sustainability by

soundscape monitoring and promote the applications of soundscape data from the open collaboration platform we provided will be conducted.