GLOBAL SOUNDSCAPES PROJECT

A MISSION TO RECORD THE EARTH

PURDUE UNIVERSITY

CENTER FOR GLOBAL SOUNDSCAPES

Soundscapes 101

Sound Production

Soundscape - the collection of all sounds that emanate from landscapes (Pijanowski et al. 2011)

- **Biophony** – sounds created by organisms. Signals carry information therefore are complex.
- **Geophony** – sounds from the movement of fluids -- wind and water -- change in energy. Driven mostly by climate.
- **Anthrophony** – sounds by human-made objects such as machines, tires, bells, sirens.

Keynote Species – sonic indicator species (of health or degradation)

Acoustic Niches – a species sonic space

Sound Perception

Sensory Drive – use of an animal's sensorium (all senses) to perceive the environment. Based on evolutionary Sensory Drive Framework (Endler, 1992).

Sound is used by animals for

Finding Mates
Social Conspecific Behaviors
Predatory-prey Relationships
Navigation

Auditory Filter – sensing of sound in organisms varies widely

Functional diversity

Sound Perception

Sensory Experience – humans use sound for:

Sense of Place – Tuan and Feld
Sonic Memories – Gibson
TEK (songs, poems) - Birkes
Multispecies Communication
Sensing Environmental Change

Emotional Triggers – certain sounds make people happy, stressed out, curious, and relaxed

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GLOBAL SOUNDSCAPES PROJECT

Bryan Pijanowski

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Francisco Rivas

Jinha Jung

Arnav Goel

Jingjing Liang

Soundscapes – Animal Diversity & Assist with Silent Remote Sensing + Develop Framework

UAV and ISS Remote Sensing Analysis

Biodiversity Metrics for Plants and Animals + *in situ* Forest Diversity Data

Core People

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Mega City
3 years at 3 sites
Expanding to 100 restoration sites

Temperate Forests
15 years at 7 sites

Mixed-Deciduous Forests
2 years at
26 sites at Leopold

Boreal Forests
1 year at 2 sites
30+ sites in 2023

4 more to go!

Subarctic
3 days test of equipment in near freezing condition

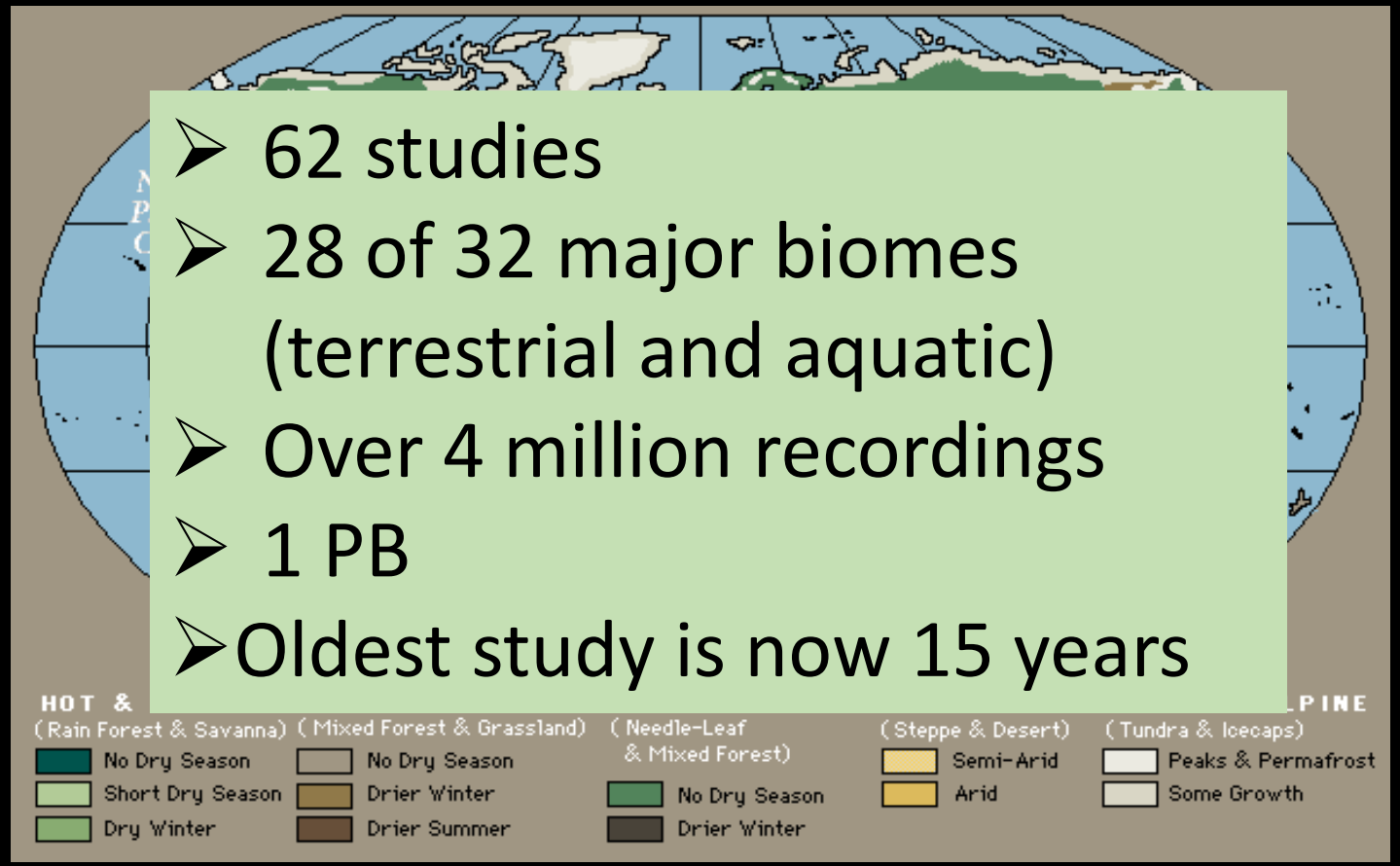
Central Grasslands (2)
2 years in prairie remnants

Dry Mediterranean
2 years in NAPA vineyards

Sonoran Desert
3 years in 7 life zones in Sky Island

Neotropical Rainforest
2.5 years in 7 sites
0.5 years in 24 sites

Kelp Forests
2.5 years in 6 sites



- 62 studies
- 28 of 32 major biomes (terrestrial and aquatic)
- Over 4 million recordings
- 1 PB
- Oldest study is now 15 years

Temperate Estuaries
3 years at 7 sites
4 months at 23 sites (2 hydrophones)

Eastern Steppes
1.5 years at 27 sites including 2 ultrasonic

Paleotropics (Borneo)
3 months at 22 sites

Mangroves
3 years at 7 sites

Miombo Woodlands
5 years at 7 sites

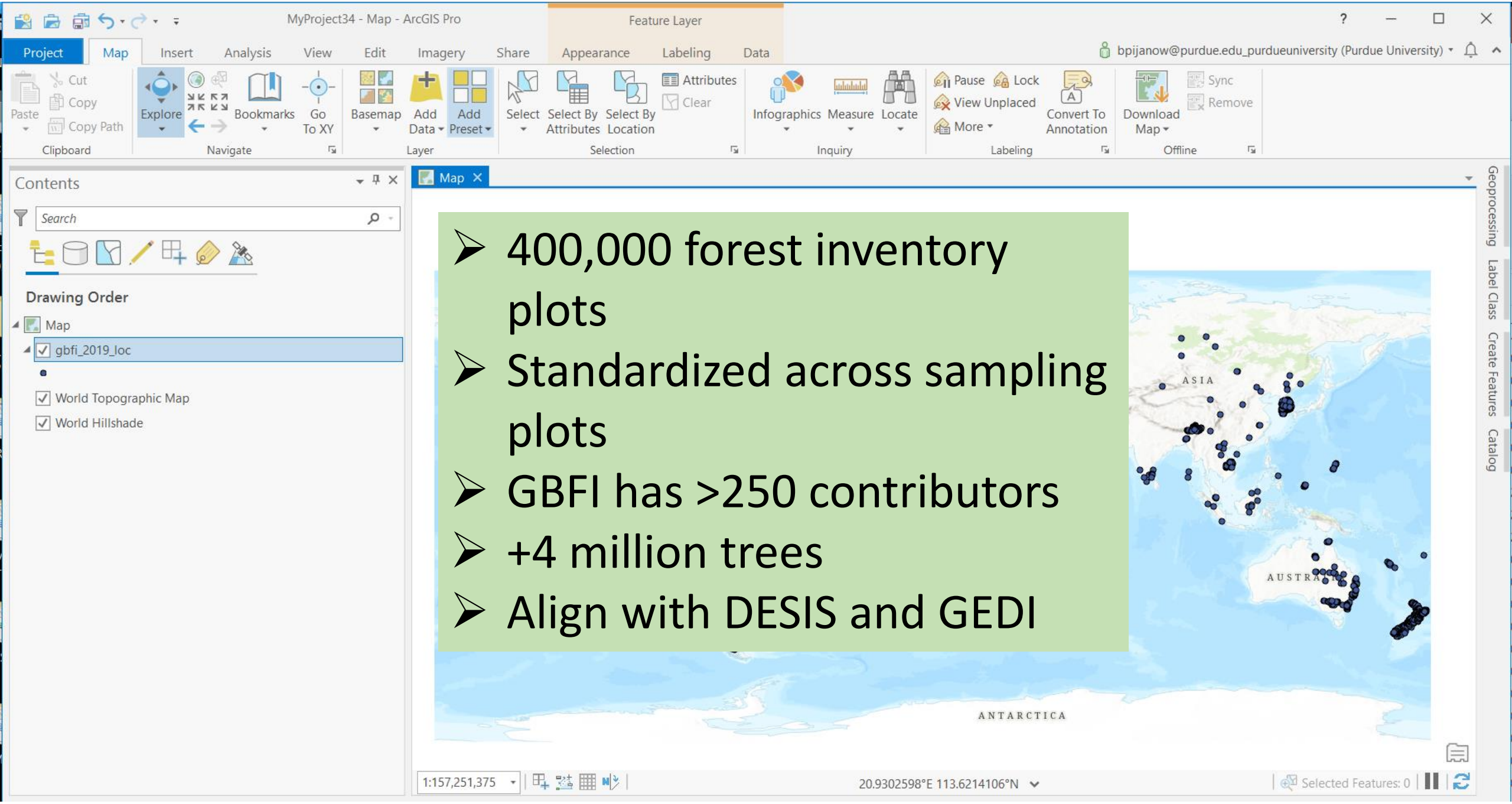
Tropical Ponds
6 months years at 1 site

Southern Temperate Forests
6 weeks in glaciers
Along prim success

Sub Antarctic
12 months in bird/mammal colonies
9 months beaver study

Amazon Forest
12 months at 2 sites

Coral Reefs
24 months at 4 sites


MyProject34 - Map - ArcGIS Pro
Feature Layer
Project
Map
Insert
Analysis
View
Edit
Imagery
Share
Appearance
Labeling
Data
bpijanow@purdue.edu_purdueuniversity (Purdue University)
Paste
Cut
Copy
Copy Path
Clipboard
Explore
Bookmarks
Go To XY
Navigate
Basemap
Add Data
Add Preset
Layer
Select
Select By Attributes
Select By Location
Attributes
Clear
Selection
Infographics
Measure
Locate
Inquiry
Pause
Lock
View Unplaced
More
Convert To Annotation
Labeling
Download Map
Sync
Remove
Offline
Contents
Search
Drawing Order
Map
gbfi_2019_loc
World Topographic Map
World Hillshade
Map
400,000 forest inventory plots
Standardized across sampling plots
GBFI has >250 contributors
+4 million trees
Align with DESIS and GEDI
ASIA
AUSTRA
ANTARCTICA
Geoprocessing
Label Class
Create Features
Catalog
1:157,251,375
20.9302598°E 113.6214106°N
Selected Features: 0

Objectives

Our vision is to use three ISS sensor platforms (GEDI, DESIS and ECOSTRESS), a variety of space-based remote sensing platforms (e.g., MODIS, Landsat, ICESat 1/2), *in situ* acoustic sensor data, and an assortment of other "silent" in situ data (field surveys, national and regional forest inventory data, UAV data, and meteorological data) to build a multi-sensor biodiversity modeling framework that is applied to major terrestrial global biomes.

- Animal + Plant Biodiversity Model

Kinds of Data We Collect

Passive Acoustic Recorders are Placed on Trees or Posts & Sometimes Integrated with Other Sensors

Sensor Installation in Mongolia in 2022

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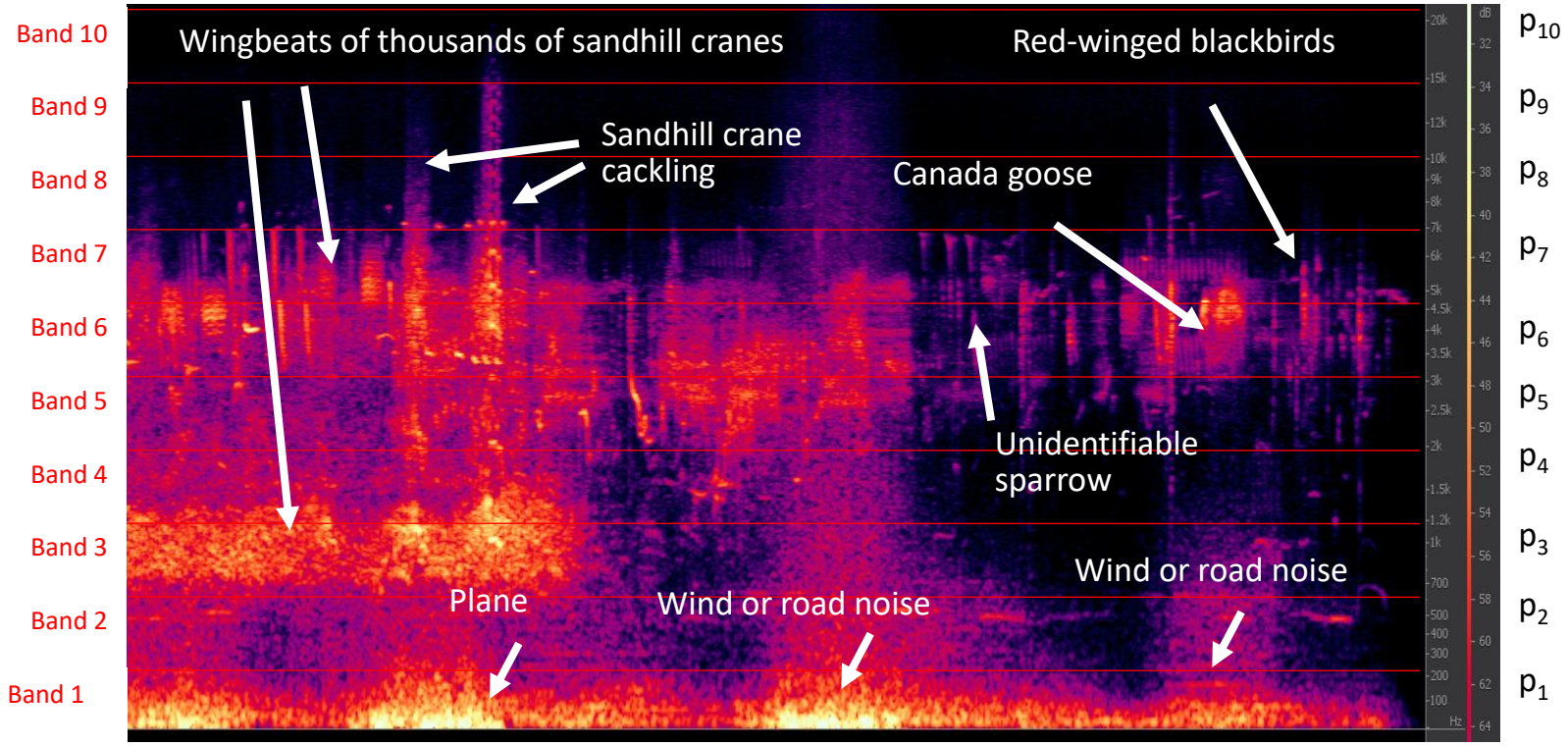
1. Use of Spectrogram Discretization to Calculate Acoustic Indices

A. Frequency Band Discretization of a Spectrogram



B. Indices based on Frequency Band Discretization

Acoustic Diversity Index (Frequency Band Entropy)

$$\beta_{t,l} = \sum_{i=1}^{N} p_i * \ln p_i \Big/ N$$

Others Include

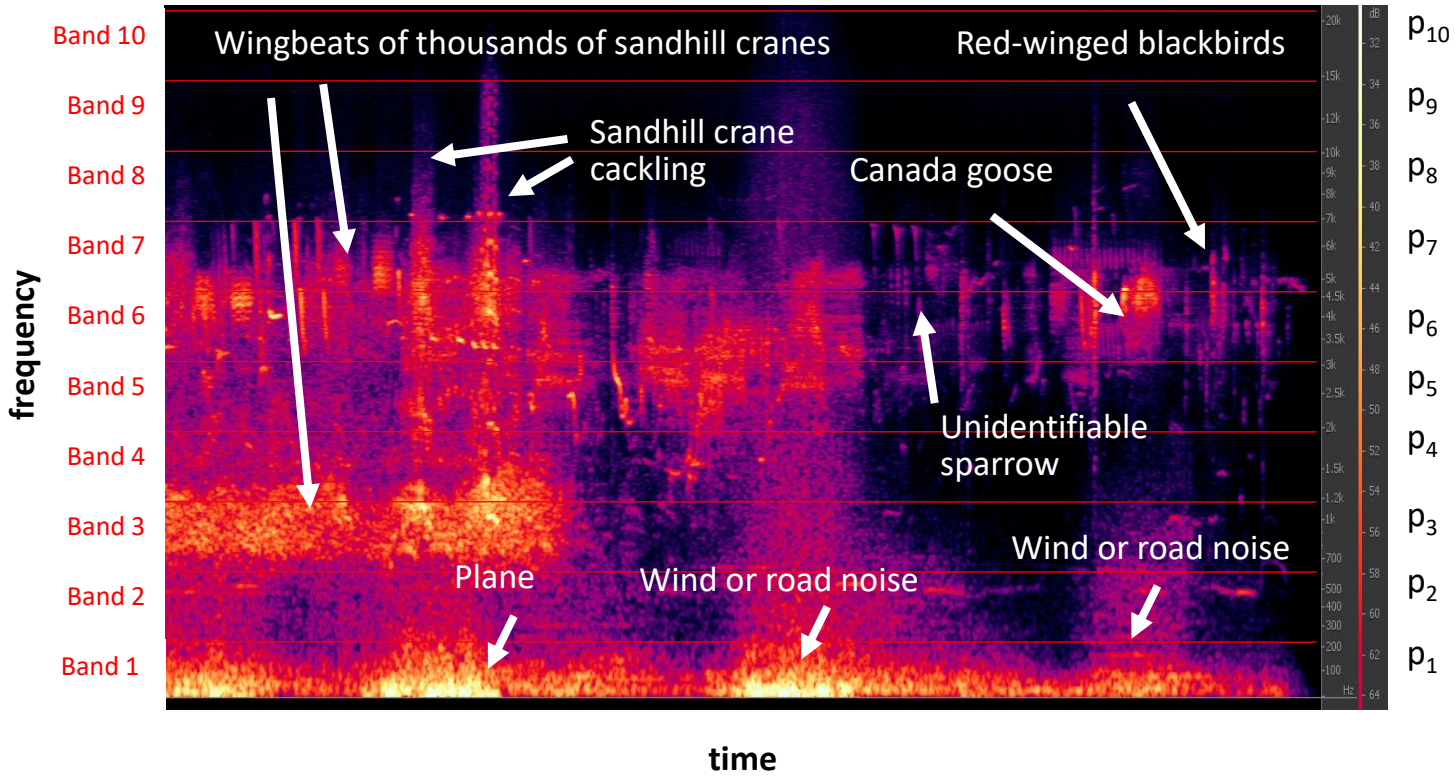
H (spectral and temporal entropy)
ACI (Acoustic Complexity Index)
BI (Bioacoustic Index)
NSDI (normalized spectral difference index)

Use SoundEcologyR

Zhao, Zhao, Zhi-yong Xu, Kristen Bellisario, Rui-wen Zeng, Ning Li, Wen-yang Zhou, and Bryan C. Pijanowski. "How well do acoustic indices measure biodiversity? Computational experiments to determine effect of sound unit shape, vocalization intensity, and frequency of vocalization occurrence on performance of acoustic indices." *Ecological Indicators* 107 (2019): 105588.

2. Use Labeled Data Using Raven Pro – Acoustic Morphospecies Richness

A. Frequency Band Discretization of a Spectrogram



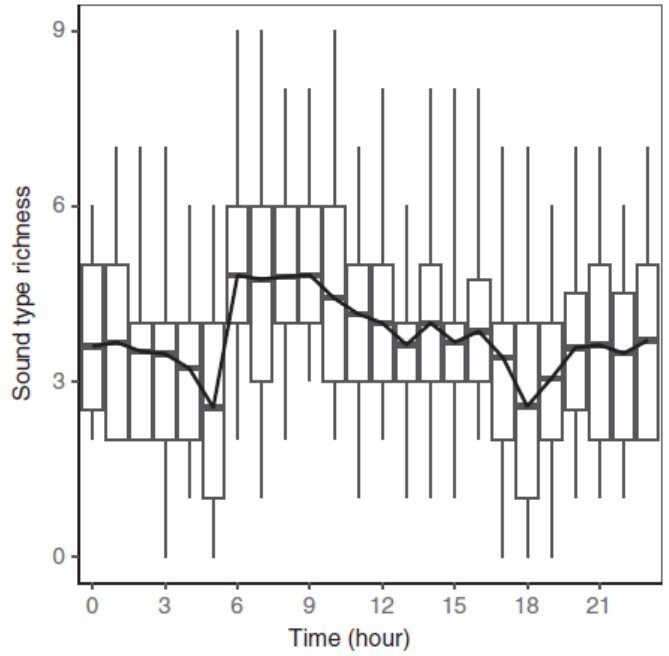
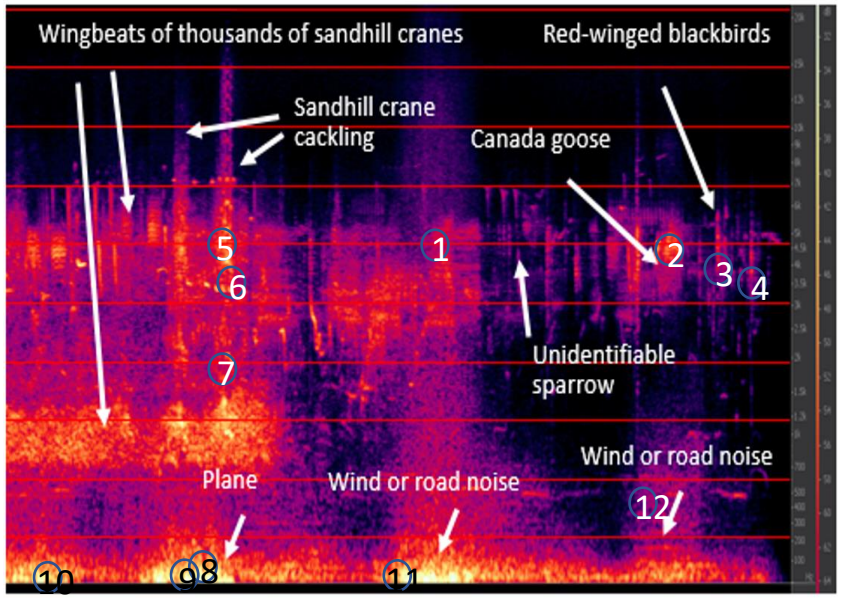
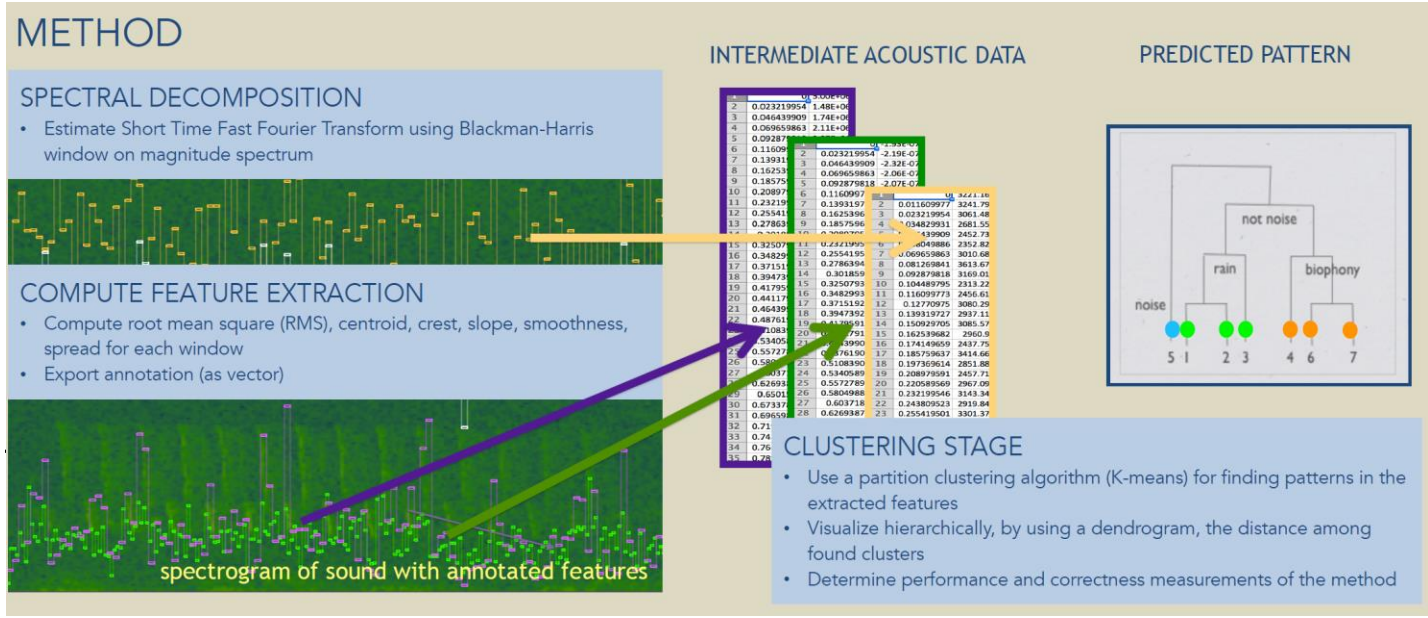


FIGURE 7 Mean sound type richness calculated for each hour. The lower bound of each box is the 25% quantile and the upper bound is the 75% quantile; whiskers extend to the minimum and maximum values for each hour

Zhao, Zhao, Zhi-yong Xu, Kristen Bellisario, Rui-wen Zeng, Ning Li, Wen-yang Zhou, and Bryan C. Pijanowski. "How well do acoustic indices measure biodiversity? Computational experiments to determine effect of sound unit shape, vocalization intensity, and frequency of vocalization occurrence on performance of acoustic indices." *Ecological Indicators* 107 (2019): 105588.

#3. Use acoustic feature extraction used in computational musicology



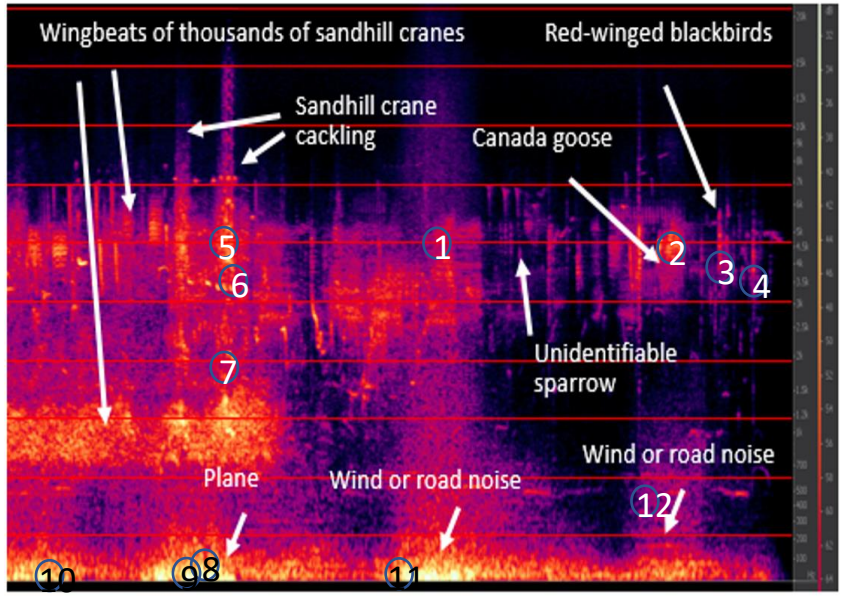


Spectral segmentation

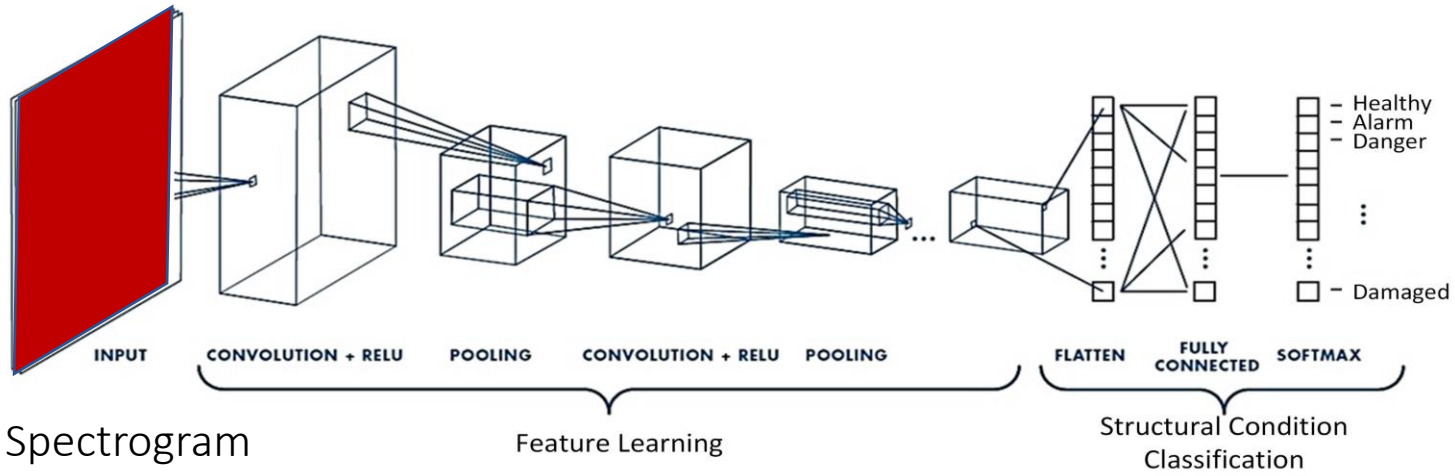
Signal clustering of unknown and known signals – millions of signals per 10 min recording

Bellisario, Kristen M., Jack Vanschaik, Zhao Zhao, Amandine Gasc, Hichem Omrani, and Bryan C. Pijanowski. "Contributions of MIR to Soundscape Ecology. Part 2: Spectral timbral analysis for discriminating soundscape components." *Ecological Informatics* 51 (2019): 1-14.

#4. Deep learning using convolutional neural networks



Labeled Data Using Raven Pro



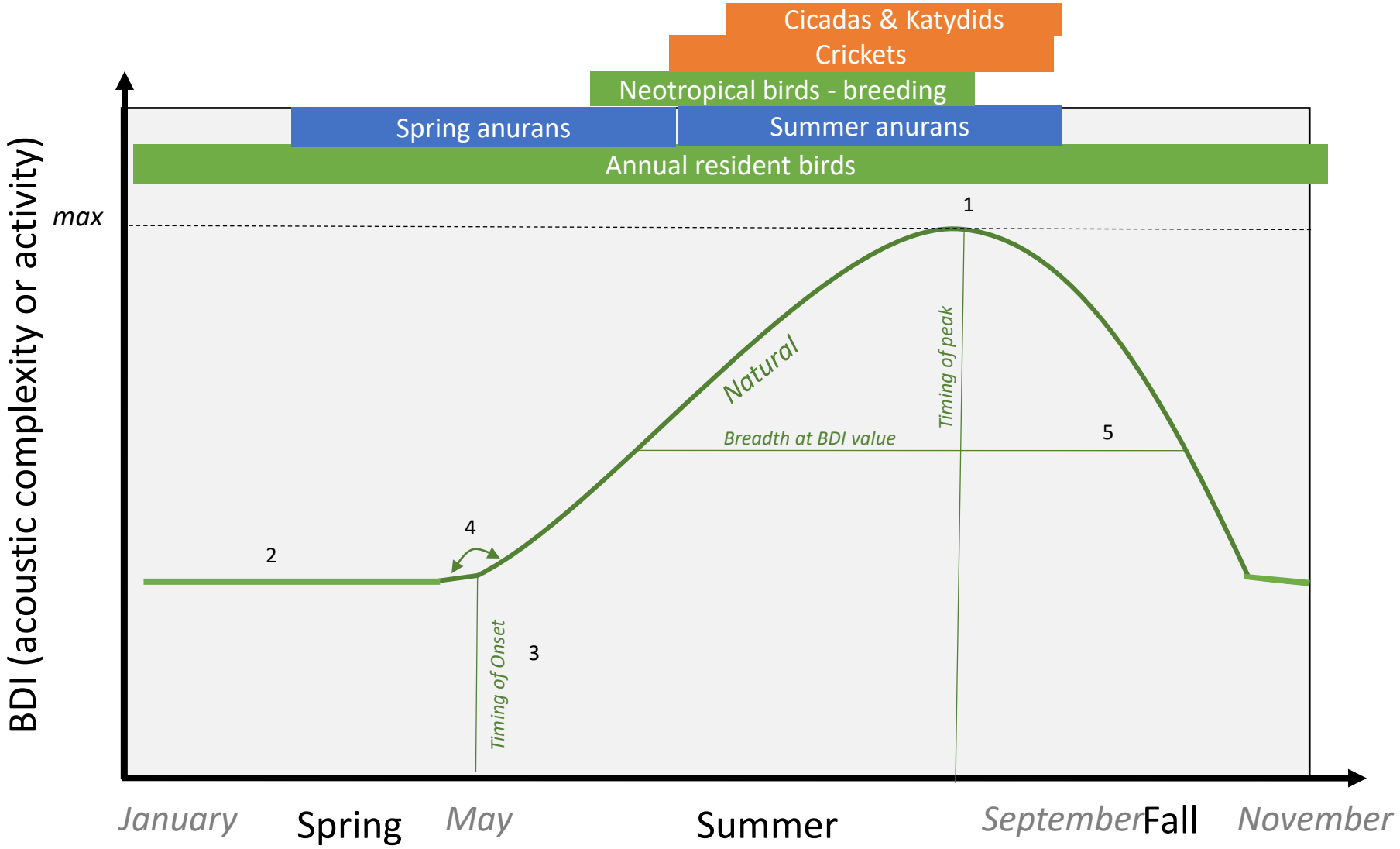
Spectrogram as png

Diagram modified from Z. Elhamraoui

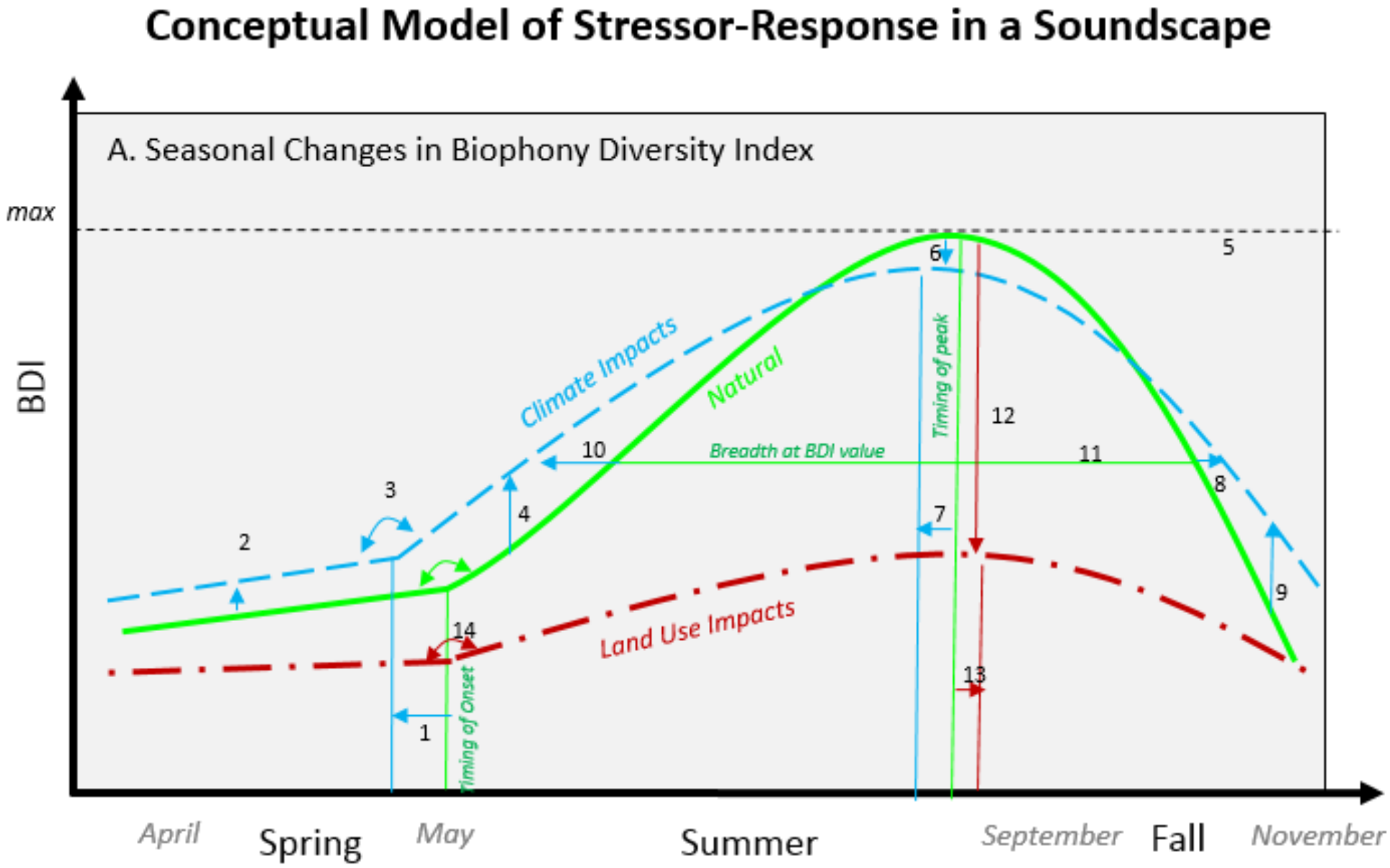
Biodiversity Framework

Conceptual Model for Temperate Forest Phonology

A. Seasonal Changes of a Biophonic Diversity Index (ACI, ADI, H, BI)



Biodiversity Framework



Experimental Design

Stressor Gradient Typical of Forest Ecosystem

	Temperate Forest
Old Growth (>10 yrs)	D,D,D,S
Old Secondary (40-100yrs)	D,D,D,S
Young Secondary (20-40yrs)	D,D,D,S
Abandoned Orchard (10-20yrs)	D,D,D,S
Mixed Forest-Cropland	D,D,D,S
Large Cropland	D,D,D,S

D=disturbance sensor, placed during max animal breeding, 10 mins on, 20 mins off, 4 months (3 sensors in this level)

S=sentinel sensor, for phonology model, recording for 3+years, 1 min on, 59 mins off (1 sensor)

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Experimental Design

	Temperate Forest		Mangroves		Steppe -Forest		Miombo Woodlands
Old Growth (>10 yrs)	D,D,D,S	High α-tree diversity, unaltered water flow	D,D,D,S	Energy giving places ID by herders	D,D,D,S	Never burned	D,D,D,S
Old Secondary (40-100yrs)	D,D,D,S	Moderate α-tree diversity, unalt. water flow	D,D,D,S	Partially damaged by insects	D,D,D,S	Burned a few times	D,D,D,S
Young Secondary (20-40yrs)	D,D,D,S	Low α-tree diversity, unalt. water flow	D,D,D,S	Completely damaged by insects	D,D,D,S	Burned moderate number of times	D,D,D,S
Abandoned Orchard (20-40yrs)	D,D,D,S	High α-tree diversity, altered. water flow	D,D,D,S	Harvested forests	D,D,D,S	Burned many times	D,D,D,S
Mixed Forest-Cropland	D,D,D,S	Moderate α-tree diversity, alt. water flow	D,D,D,S	Healthy grasslands	D,D,D,S	Burned almost all years	D,D,D,S
Large Cropland	D,D,D,S	Low α-tree diversity, alt. water flow	D,D,D,S	Degraded grasslands	D,D,D,S	Burned all years	D,D,D,S

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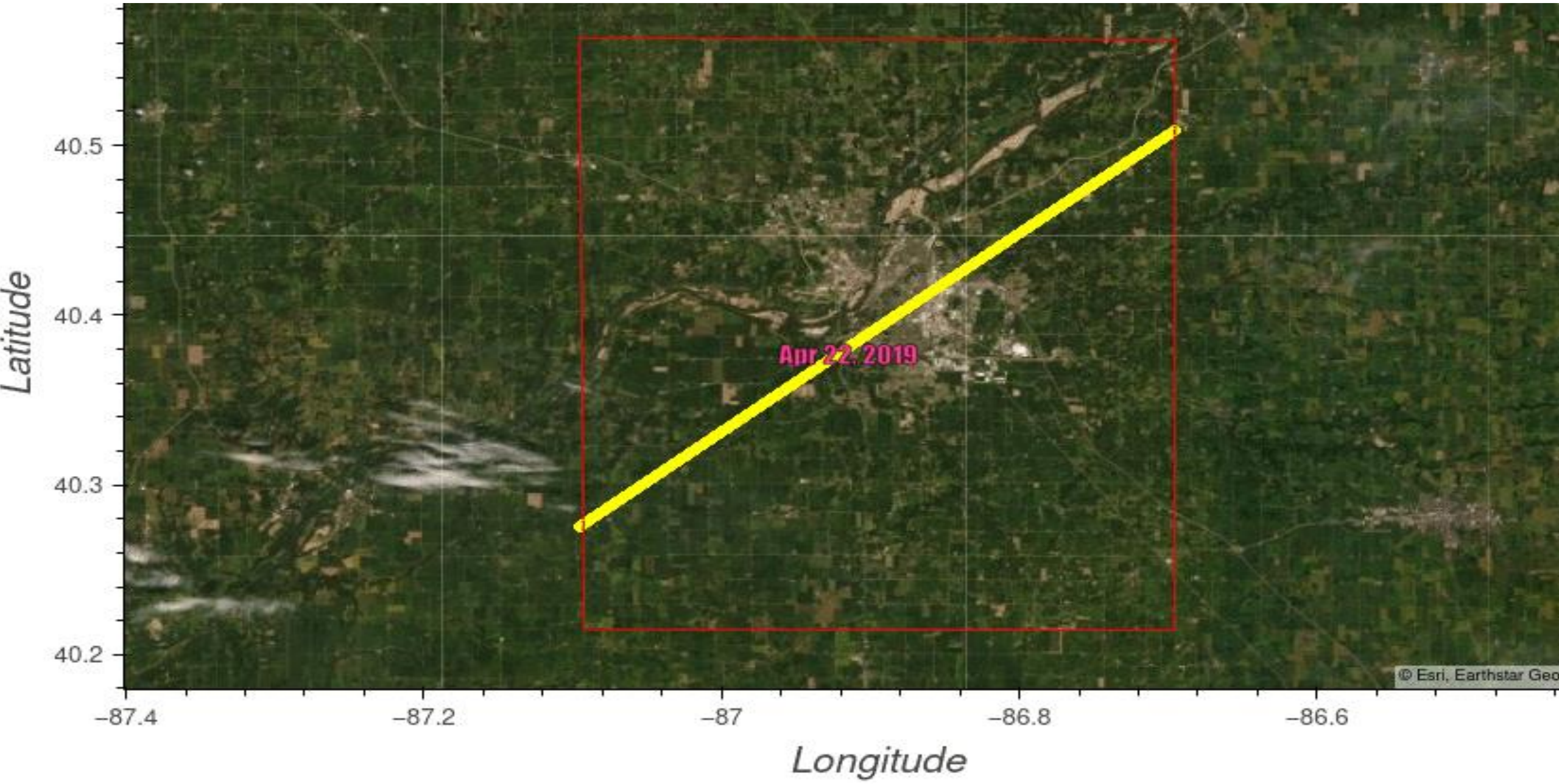
Data Collection Matrix

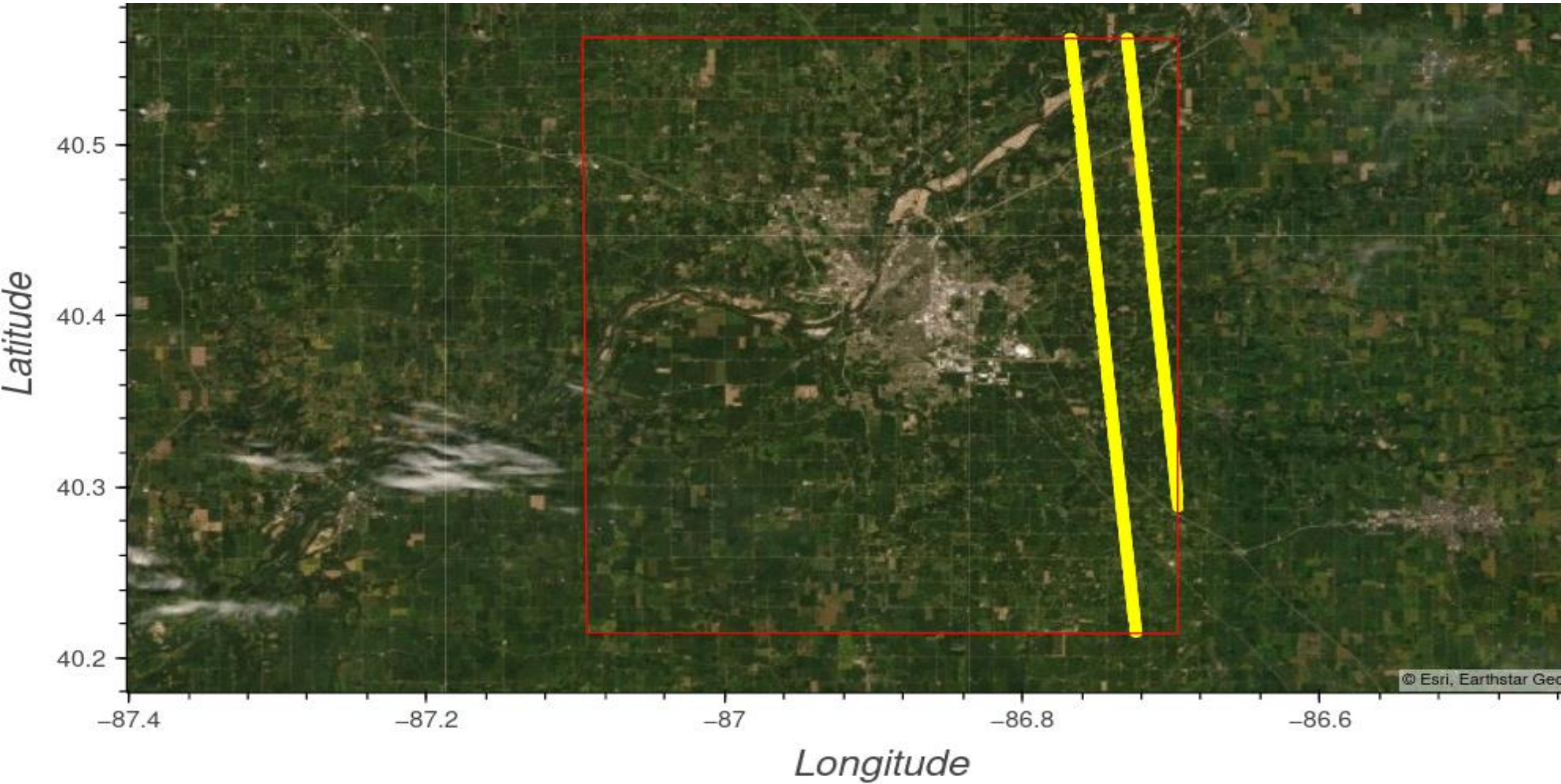
	Animal Diversity				Plant Diversity				
	Automated		*Listen & Label*		*Local in situ*		*Space-based NASA*		
	Disturbance Acoustic Sensors	**Acoustic Indices**	**Sound Source Surveys**	**Sound Labeling**	**Plant Surveys**	**UAS Mapping**	**GEDI Mapping**	**ECOSTRESS Mapping**	**MODIS EVI Mapping**
Tippecanoe Indiana									
Arkhangai, Mongolia									
Issa Valley, Tanzania									
Sundarbans, Bangladesh									

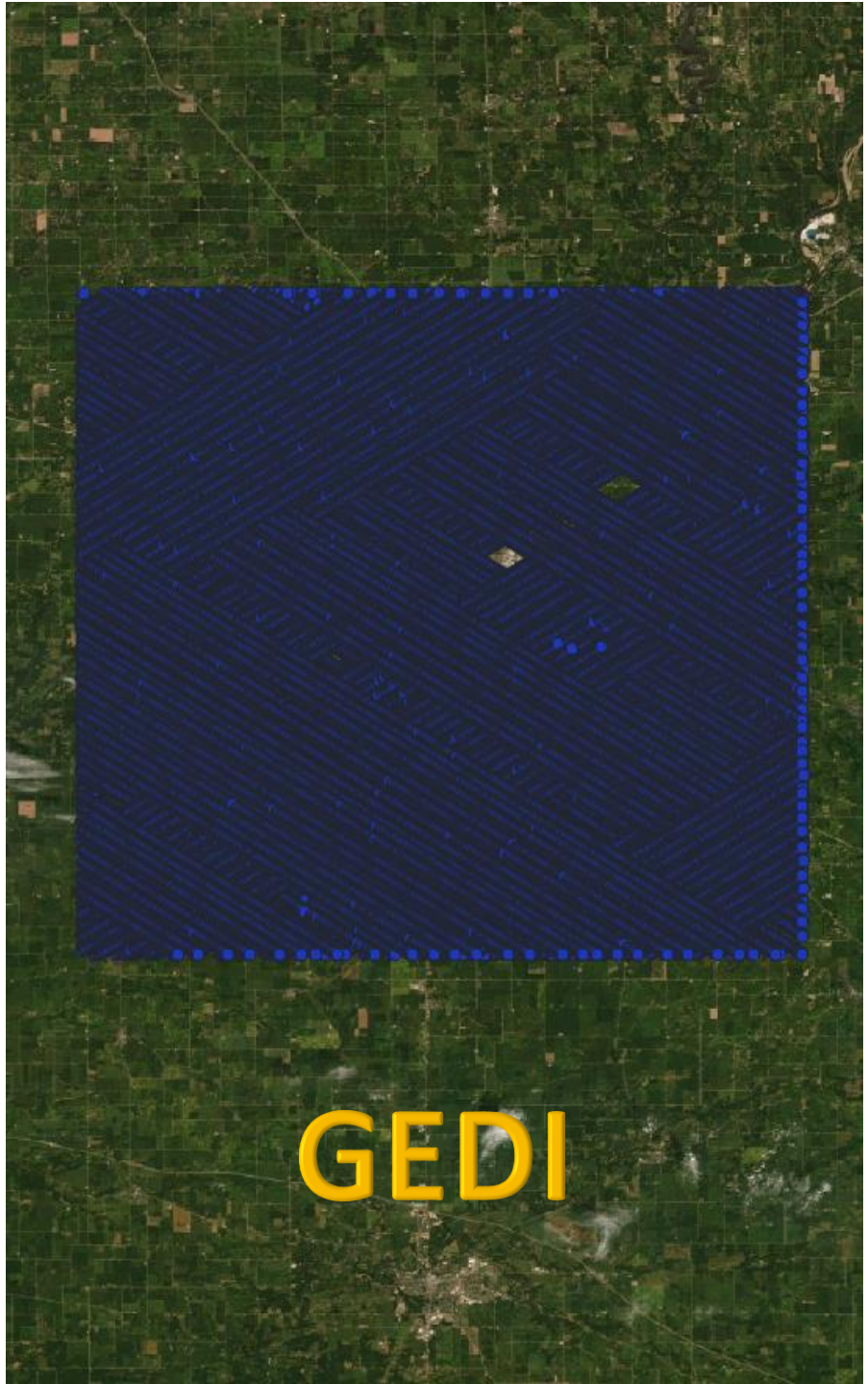

THE TEMPERATE FOREST MISSION
TO RECORD THE EARTH

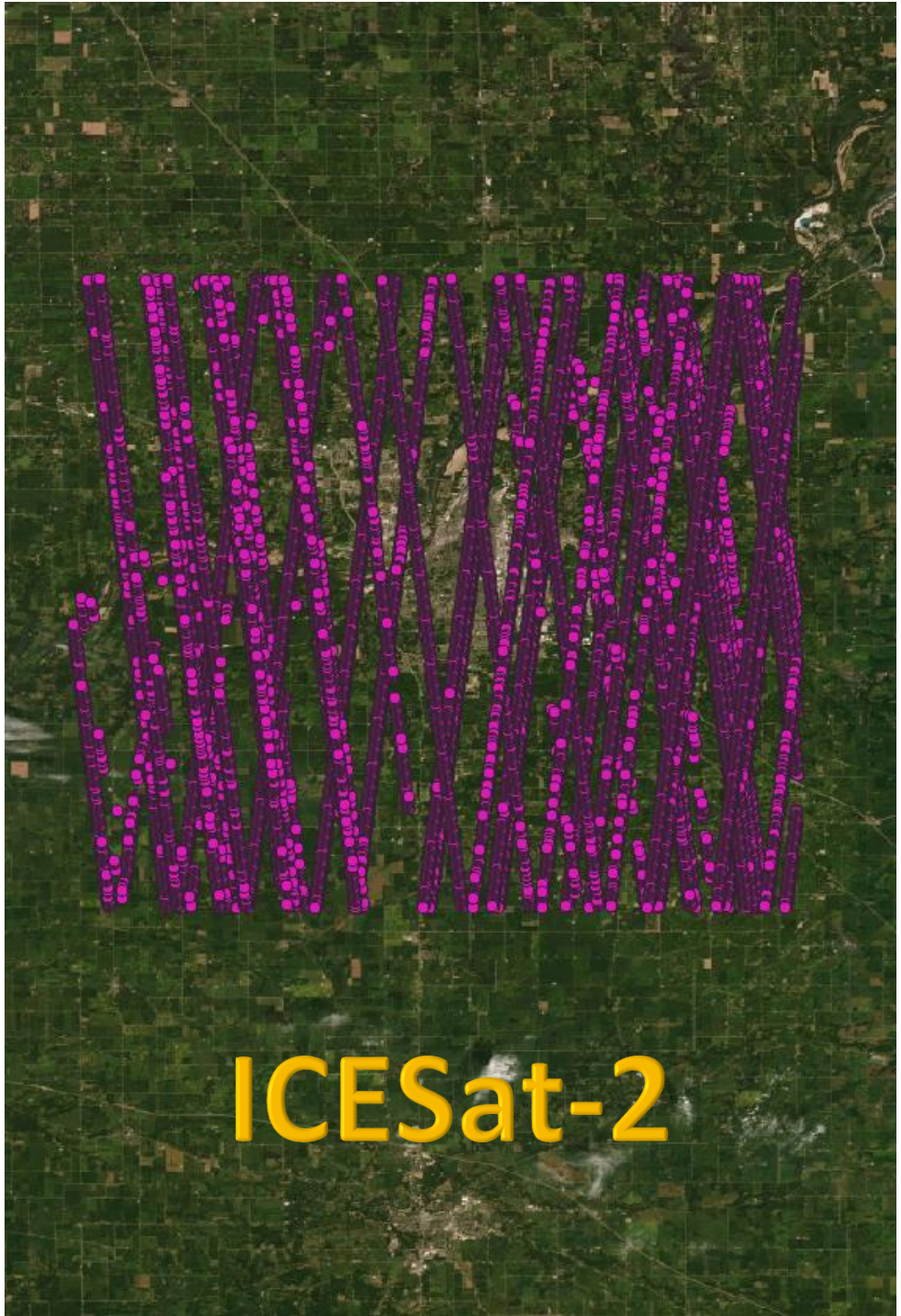
GEDI data coverage over Tippecanoe County, IN between Apr 22, 2019 – Feb 5, 2021



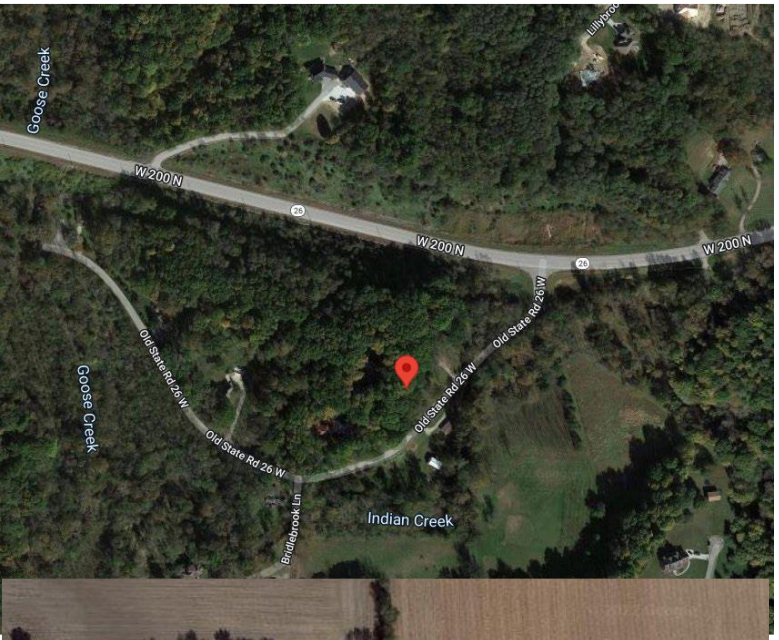
ICESat-2 data coverage over Tippecanoe County, IN between 12/26/2018 and 5/23/2021

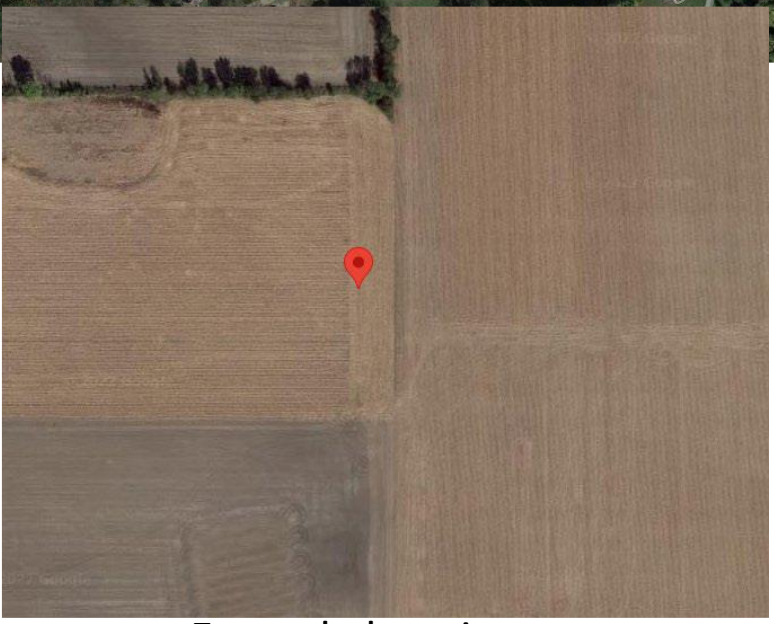



GEDI

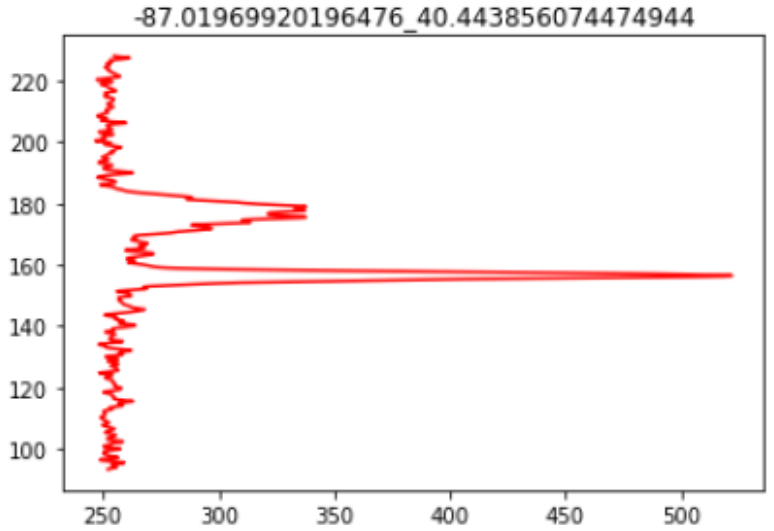

ICESat-2

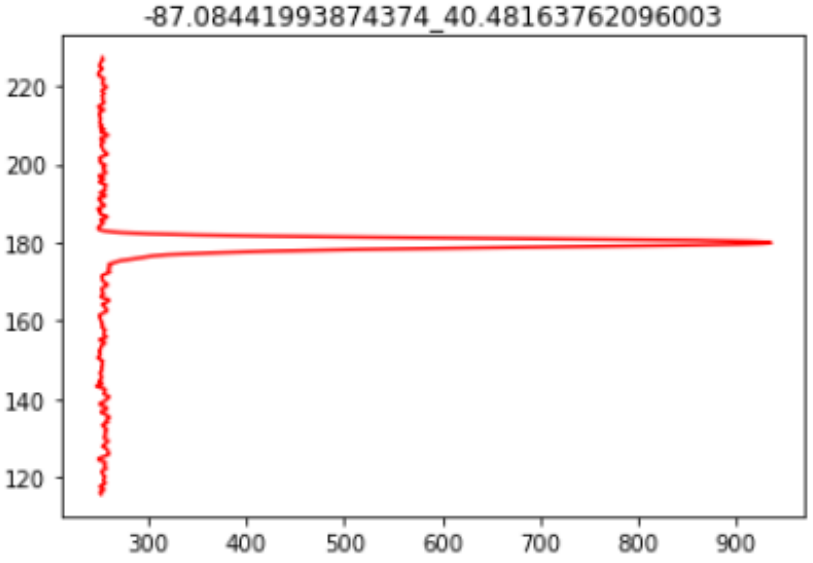
Validating GEDI full waveform data with 3DEP



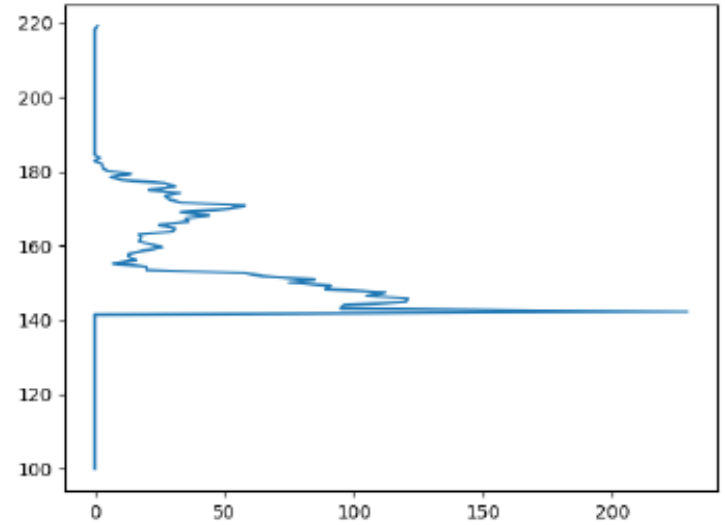


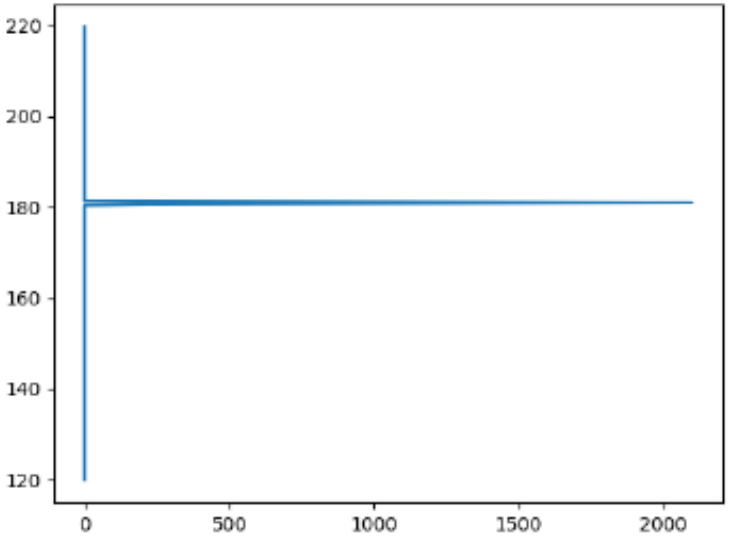
Example locations





GEDI Full Waveform





3DEP Pseudo Waveform


THE MANGROVES
MISSION
TO RECORD THE EARTH

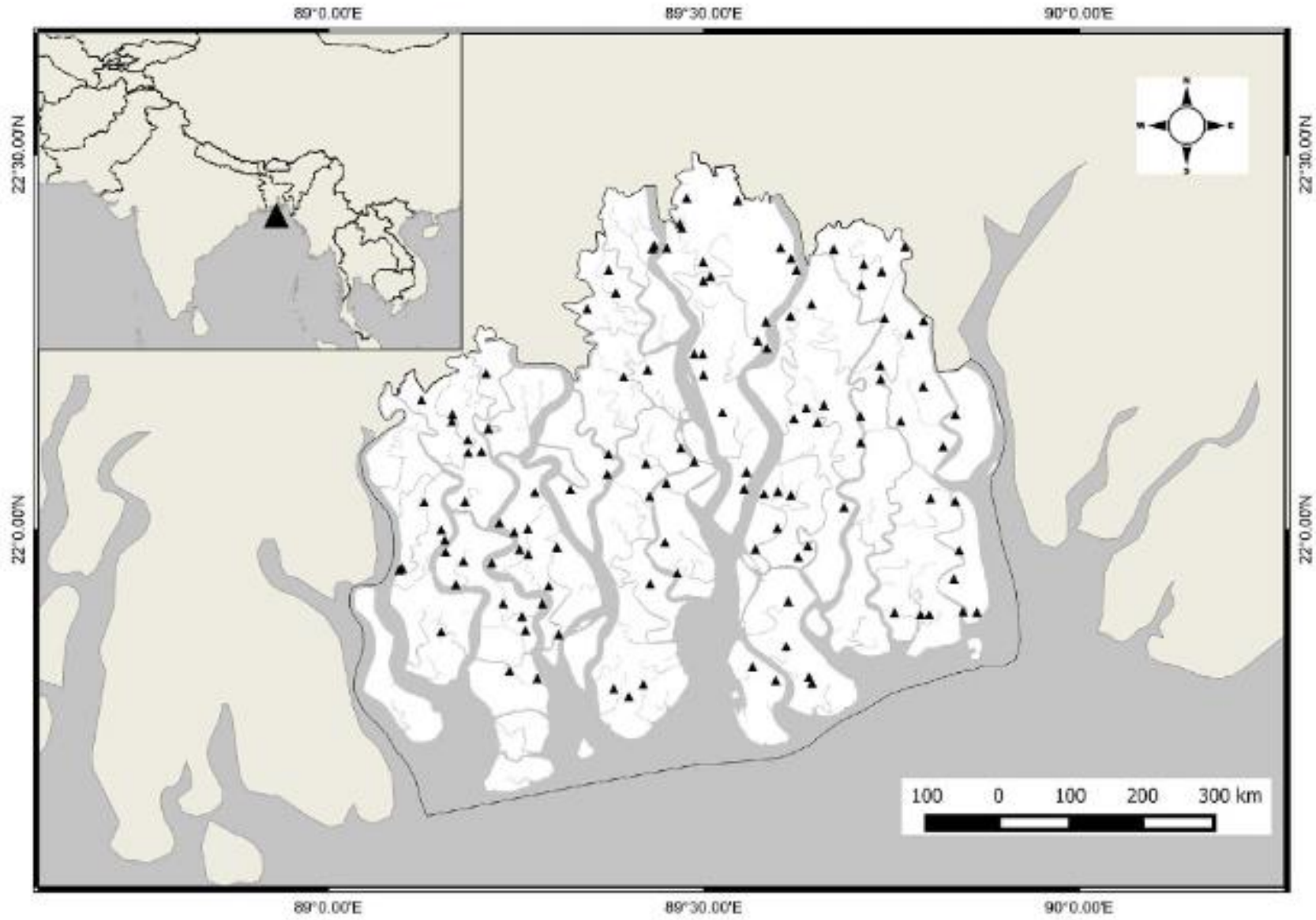
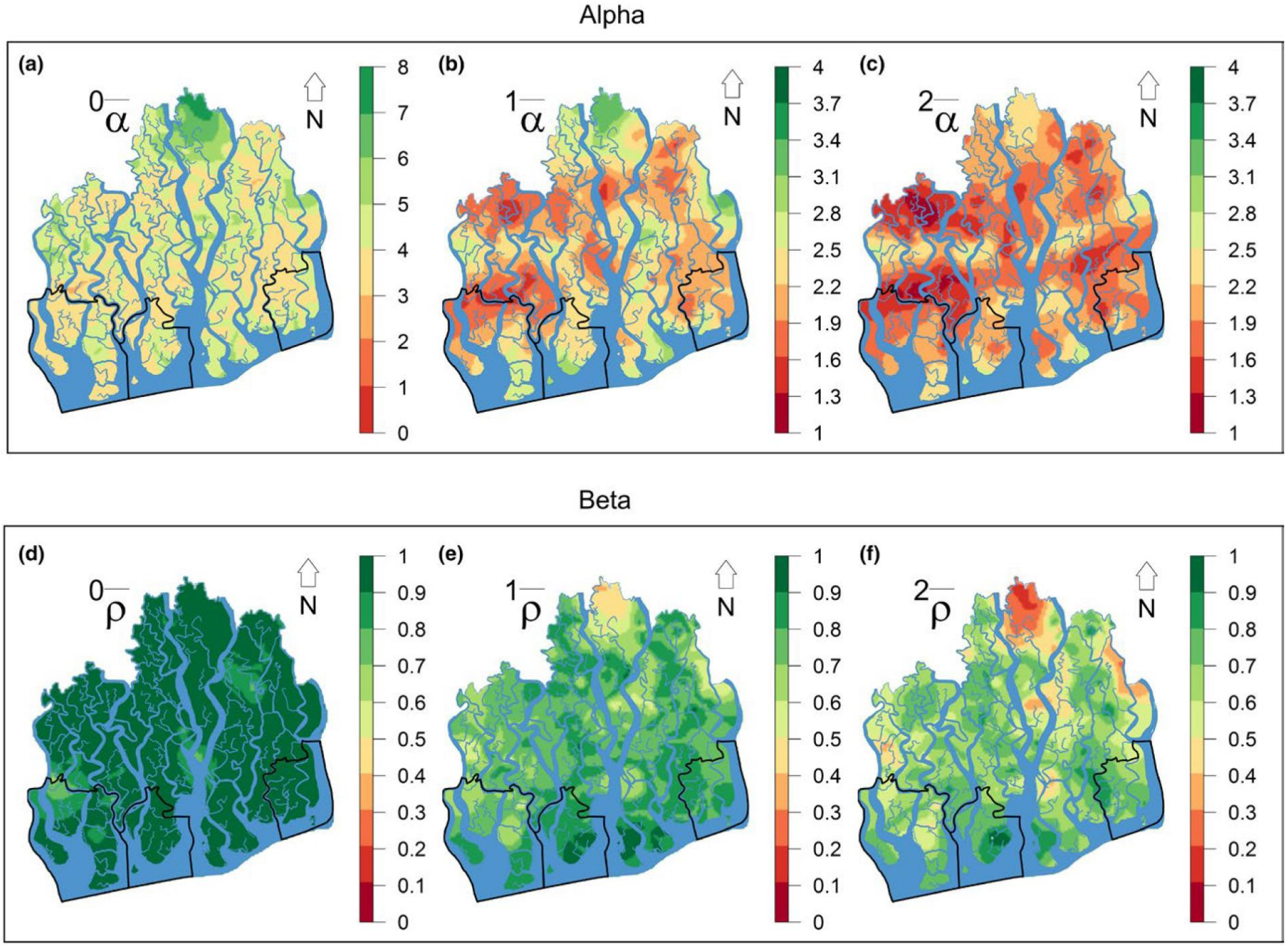
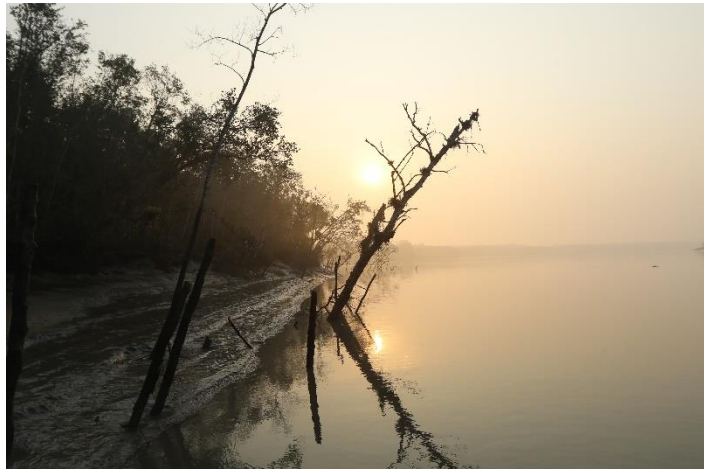


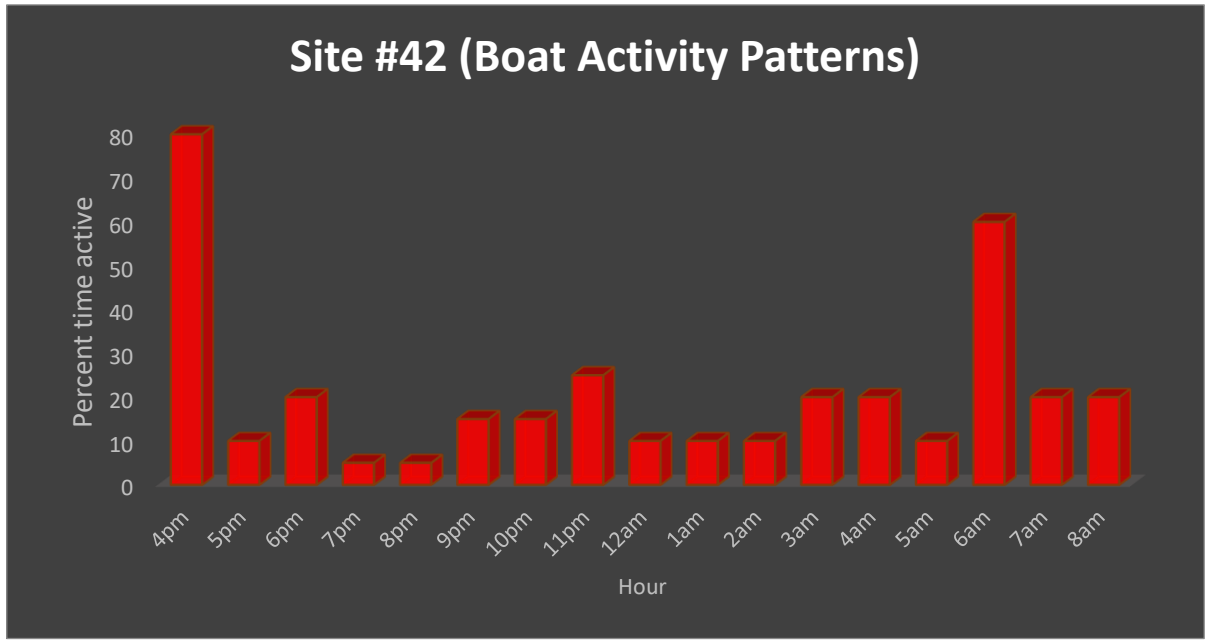
Figure 1. Sampling sites (triangles) in the Sundarbans, Bangladesh. The map was created using the software QGIS (version 2.10.1, URL: http://www.qgis.org/en/site/).

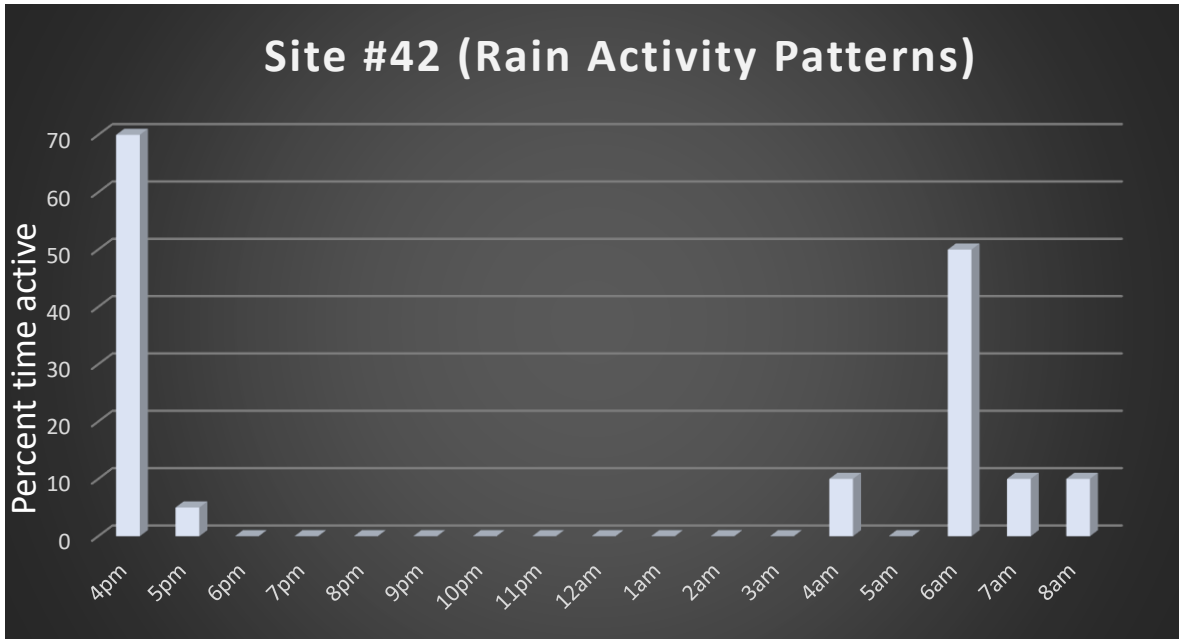

Alpha
(a)
$^{0}\alpha$
N
8
7
6
5
4
3
2
1
0
(b)
$^{1}\alpha$
N
4
3.7
3.4
3.1
2.8
2.5
2.2
1.9
1.6
1.3
1
(c)
$^{2}\alpha$
N
4
3.7
3.4
3.1
2.8
2.5
2.2
1.9
1.6
1.3
1
Beta
(d)
$^{0}\rho$
N
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
(e)
$^{1}\rho$
N
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
(f)
$^{2}\rho$
N
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0




ব্যবস্থাপনা পরিকল্পনা বিভাগ
বয়রা, খুলনা।
পি,এস,পি,প্লট নং- ৪২


PADM


Site #42 (Boat Activity Patterns)
Percent time active
80
70
60
50
40
30
20
10
0
4pm
5pm
6pm
7pm
8pm
9pm
10pm
11pm
12am
1am
2am
3am
4am
5am
6am
7am
8am
Hour


Site #42 (Rain Activity Patterns)
Percent time active
70
60
50
40
30
20
10
0
4pm
5pm
6pm
7pm
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9pm
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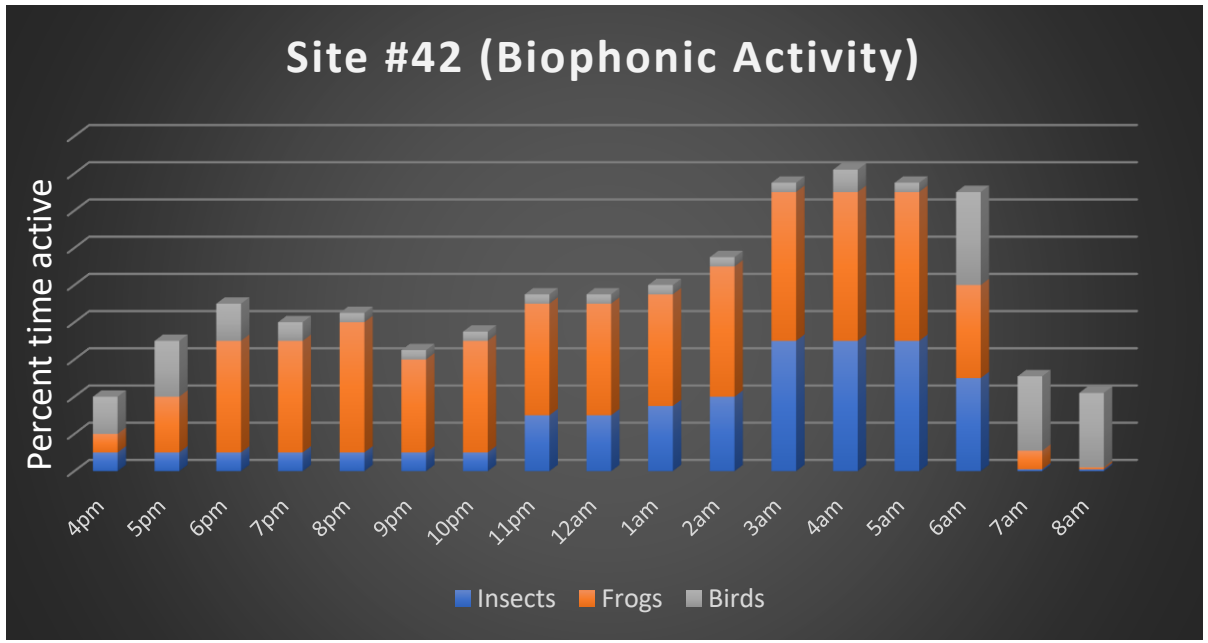
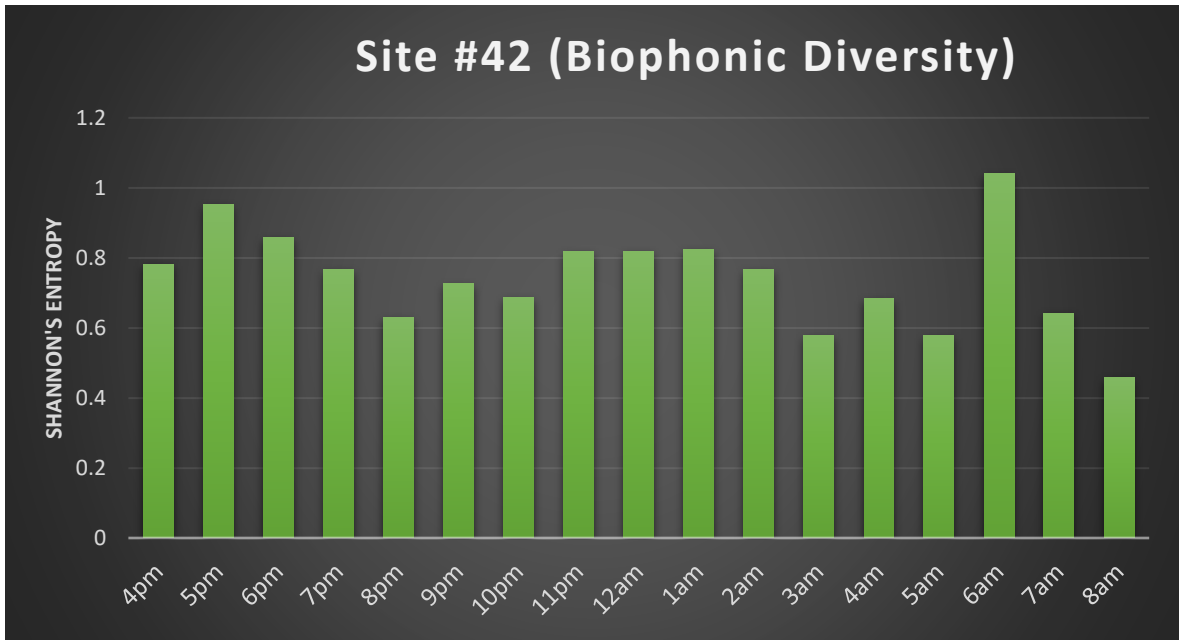
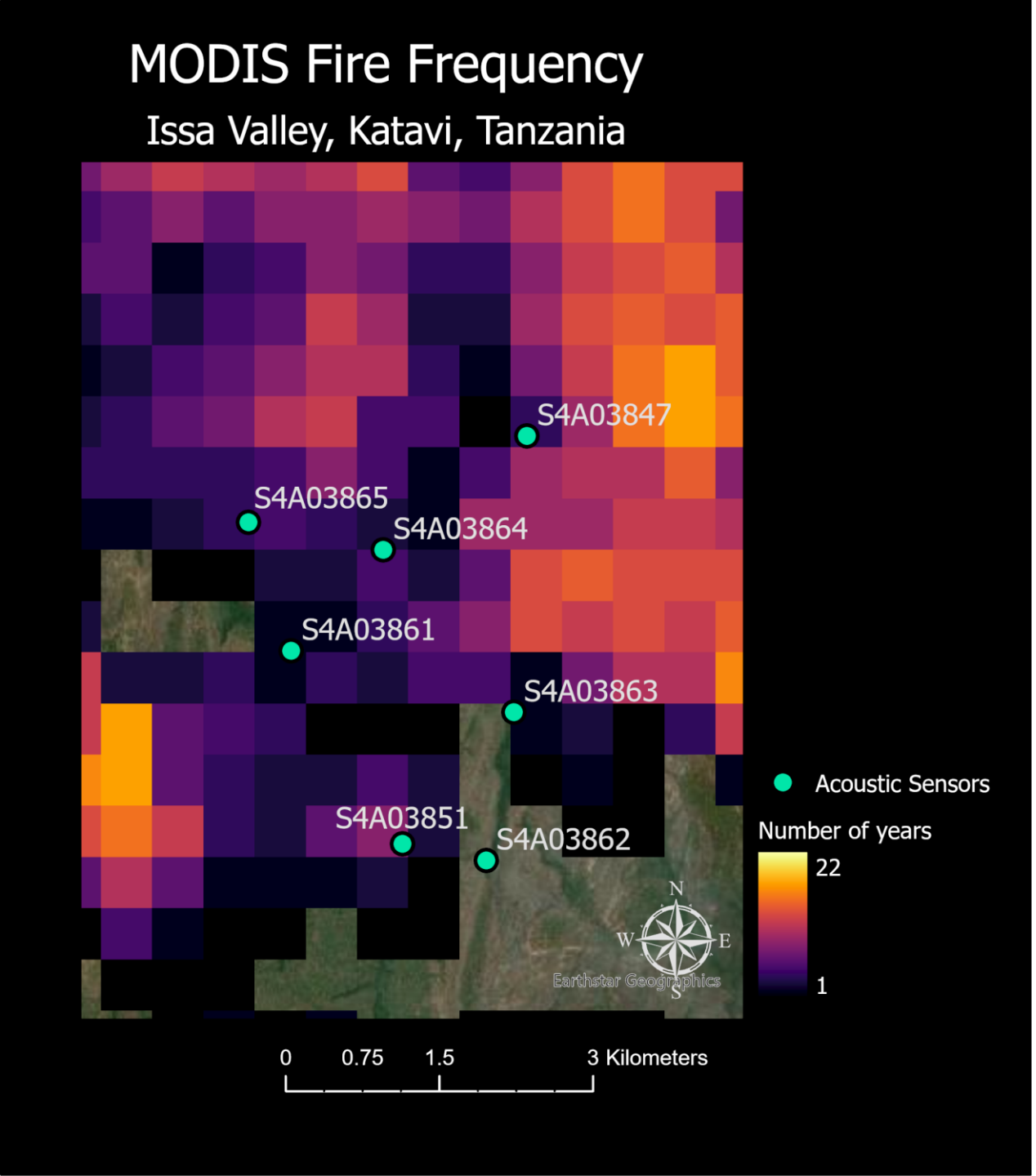
11pm
12am
1am
2am
3am
4am
5am
6am
7am
8am


Site #42 (Biophonic Activity)
Percent time active
4pm
5pm
6pm
7pm
8pm
9pm
10pm
11pm
12am
1am
2am
3am
4am
5am
6am
7am
8am
Insects
Frogs
Birds


Site #42 (Biophonic Diversity)
SHANNON'S ENTROPY
1.2
1
0.8
0.6
0.4
0.2
0
4pm
5pm
6pm
7pm
8pm
9pm
10pm
11pm
12am
1am
2am
3am
4am
5am
6am
7am
8am

THE MIOMBO WOODLANDS MISSION

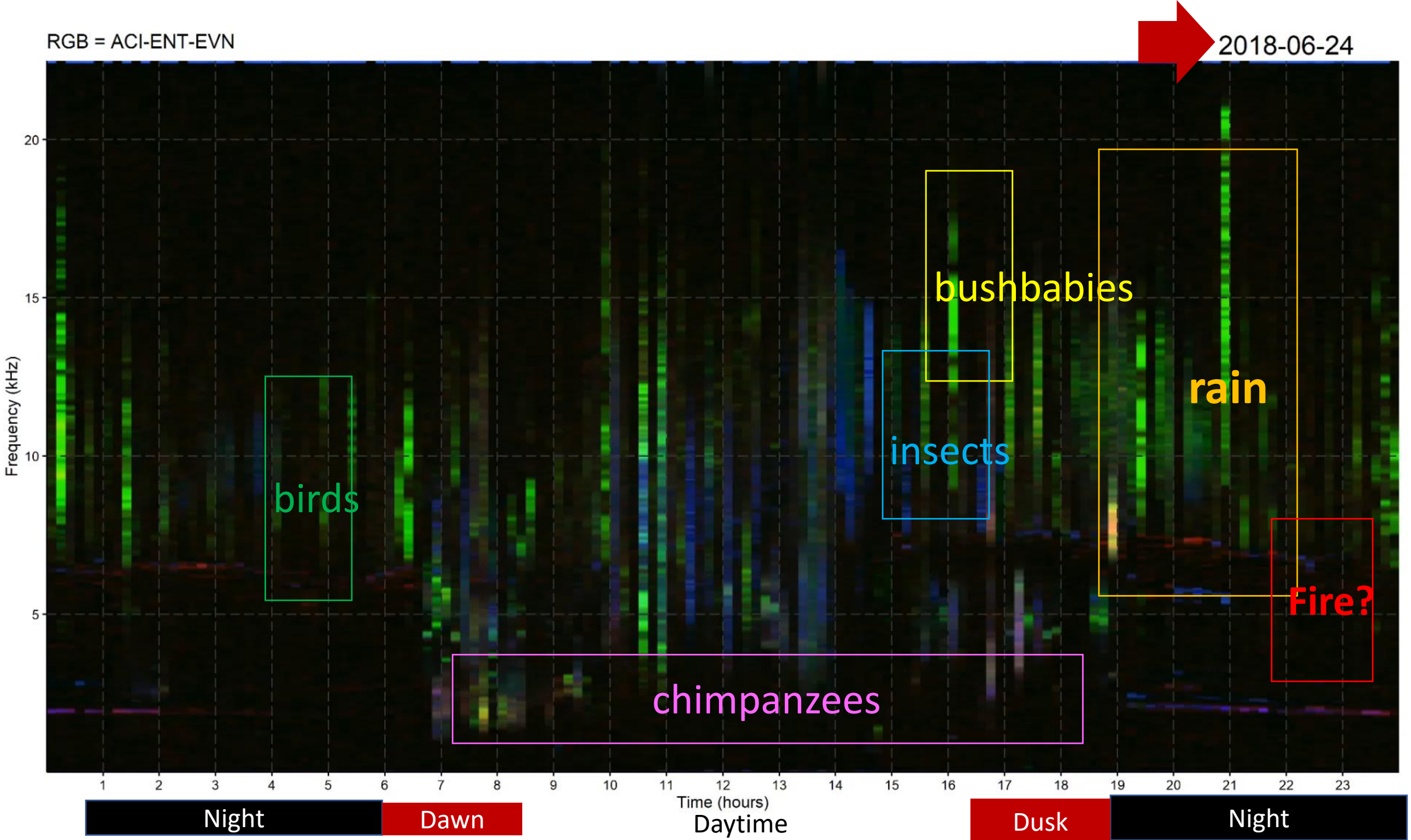
TO RECORD THE EARTH

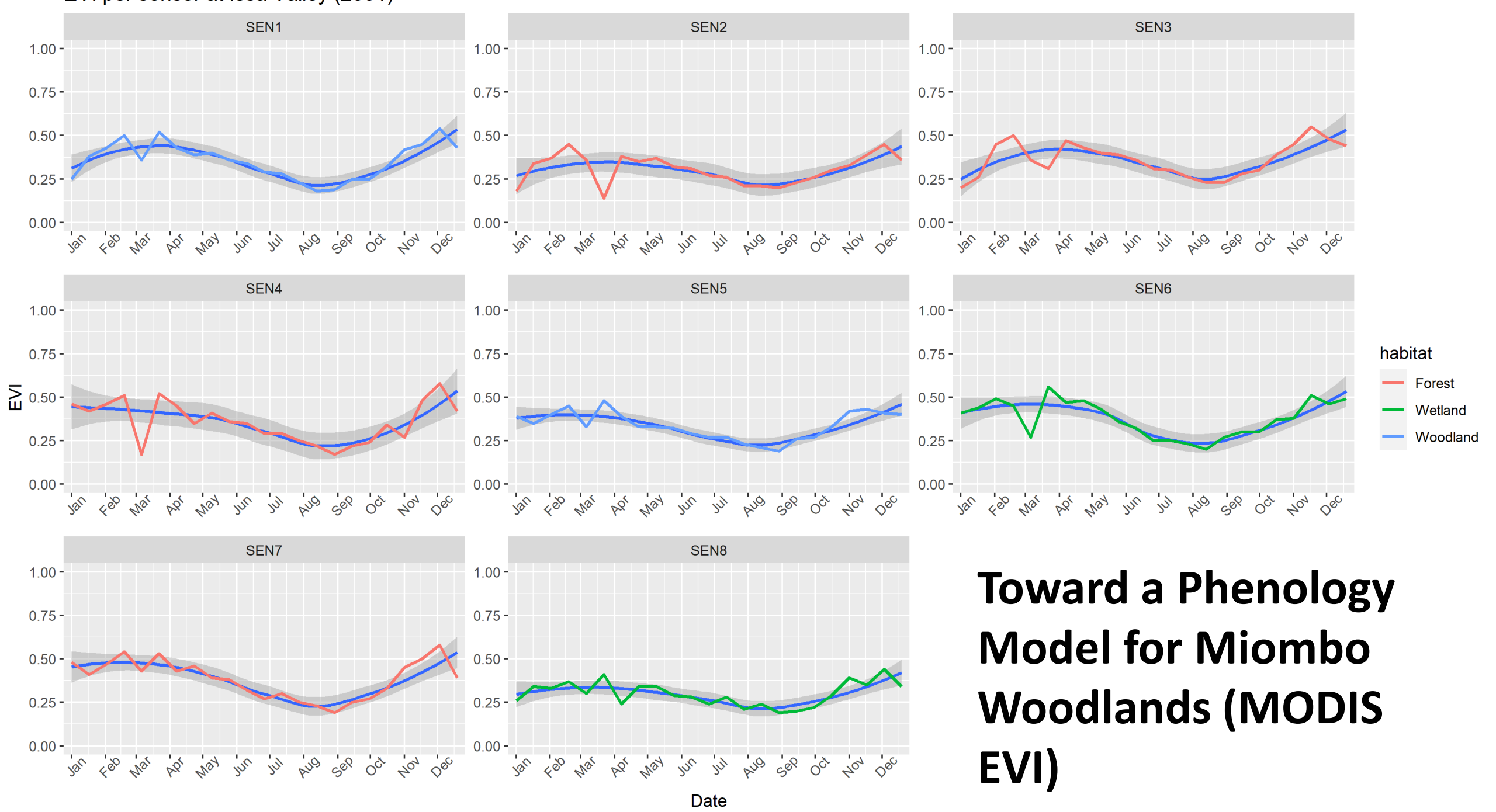


Major Stressor

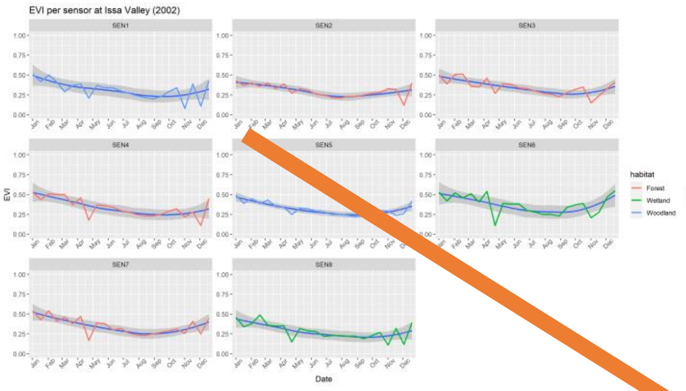
Wildfire

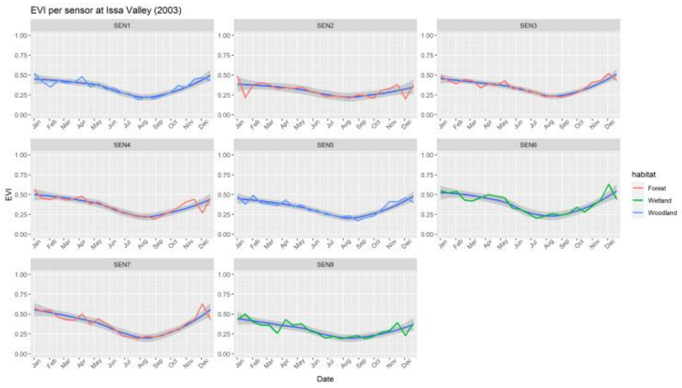
Drought

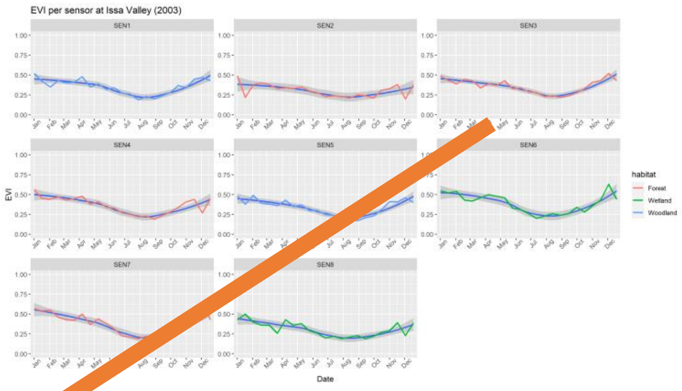

RGB = ACI-ENT-EVN
2018-06-24
bushbabies
rain
insects
birds
Fire?
chimpanzees
Frequency (kHz)
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Time (hours)
Night
Dawn
Daytime
Dusk
Night

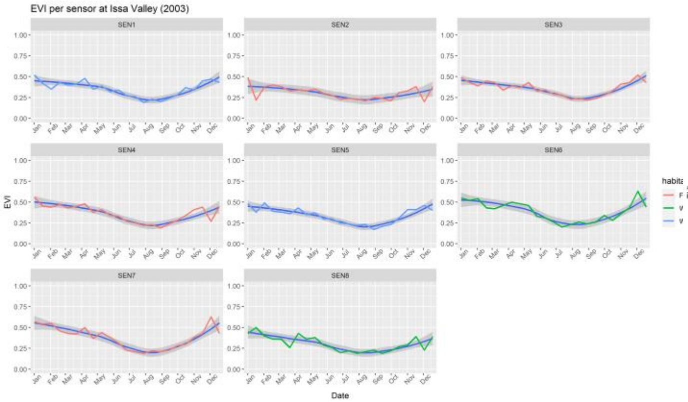


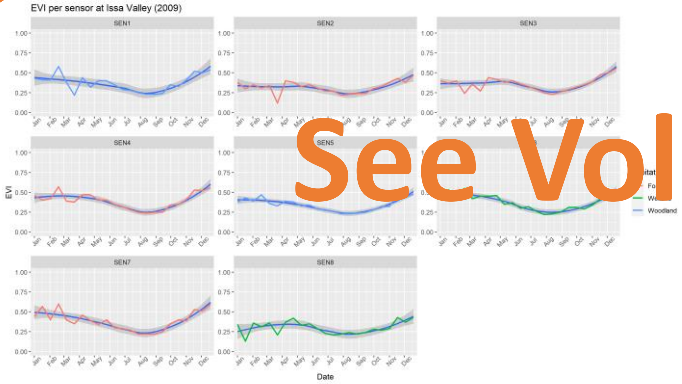
Toward a Phenology Model for Miombo Woodlands (MODIS EVI)

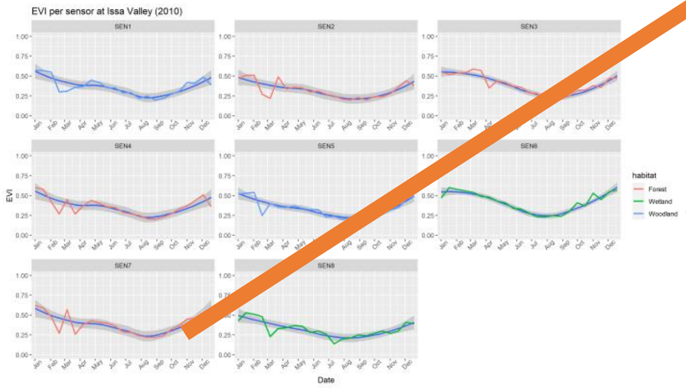


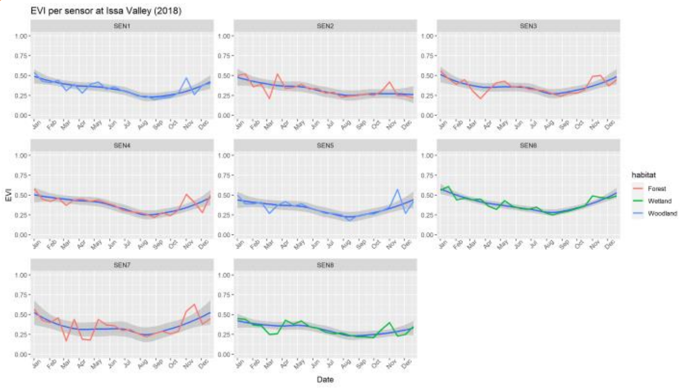












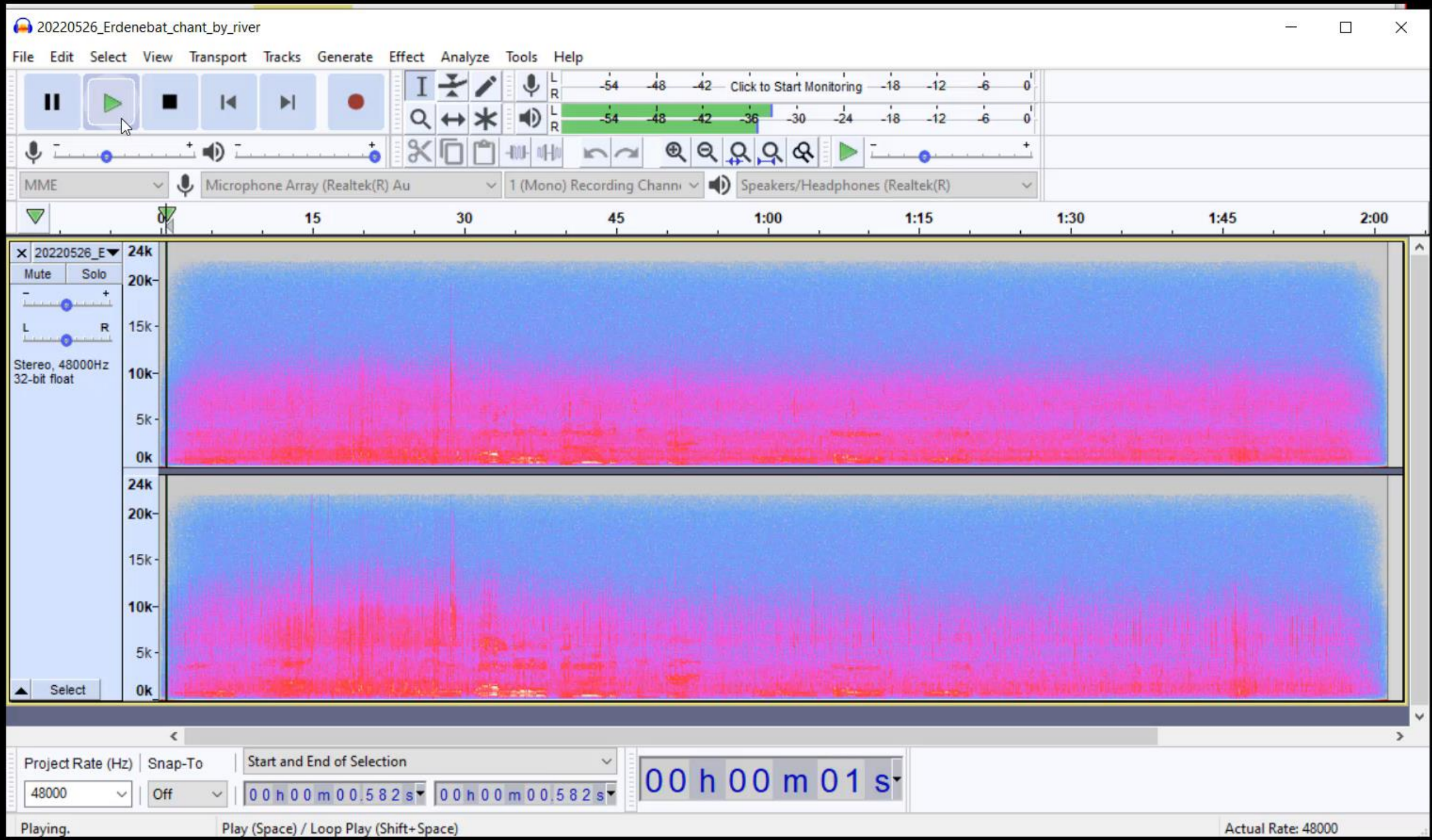
See Volker!

Toward a Phenology Model for Miombo Woodlands (2001-2021)

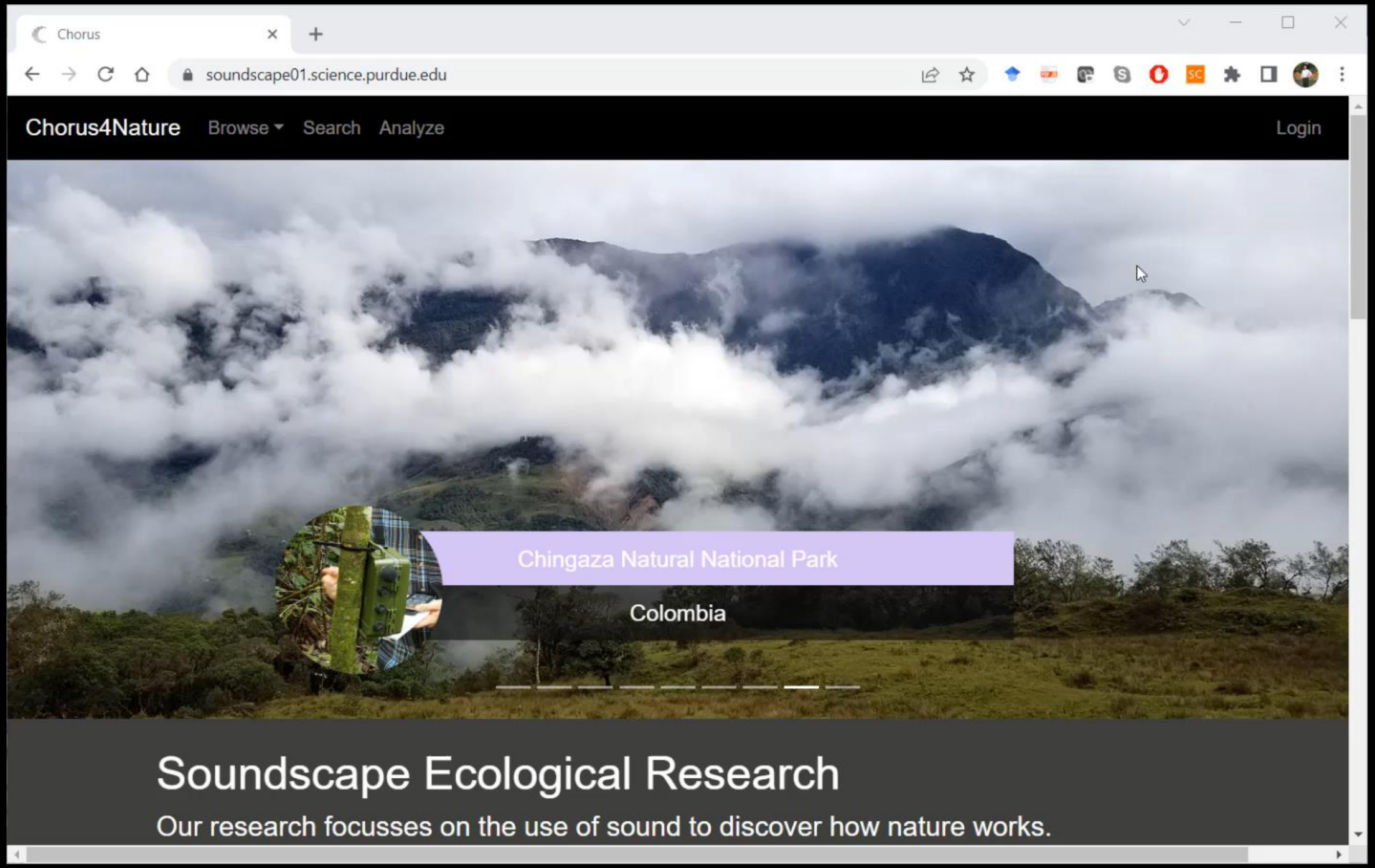
THE FOREST-STEPPE MISSION

TO RECORD THE EARTH

Co-Production Workshop June 2-4, 2022


20220526_Erdenebat_chant_by_river
File Edit Select View Transport Tracks Generate Effect Analyze Tools Help
Click to Start Monitoring
MME
Microphone Array (Realtek(R) Au
1 (Mono) Recording Chann
Speakers/Headphones (Realtek(R)
0 15 30 45 1:00 1:15 1:30 1:45 2:00
20220526_E
Mute Solo
L R
Stereo, 48000Hz
32-bit float
Select
24k 20k 15k 10k 5k 0k
Project Rate (Hz) Snap-To
Start and End of Selection
48000 Off
00 h 00 m 00.582 s
00 h 00 m 00.582 s
00 h 00 m 01 s
Playing.
Play (Space) / Loop Play (Shift+Space)
Actual Rate: 48000

http://chorus4nature.org



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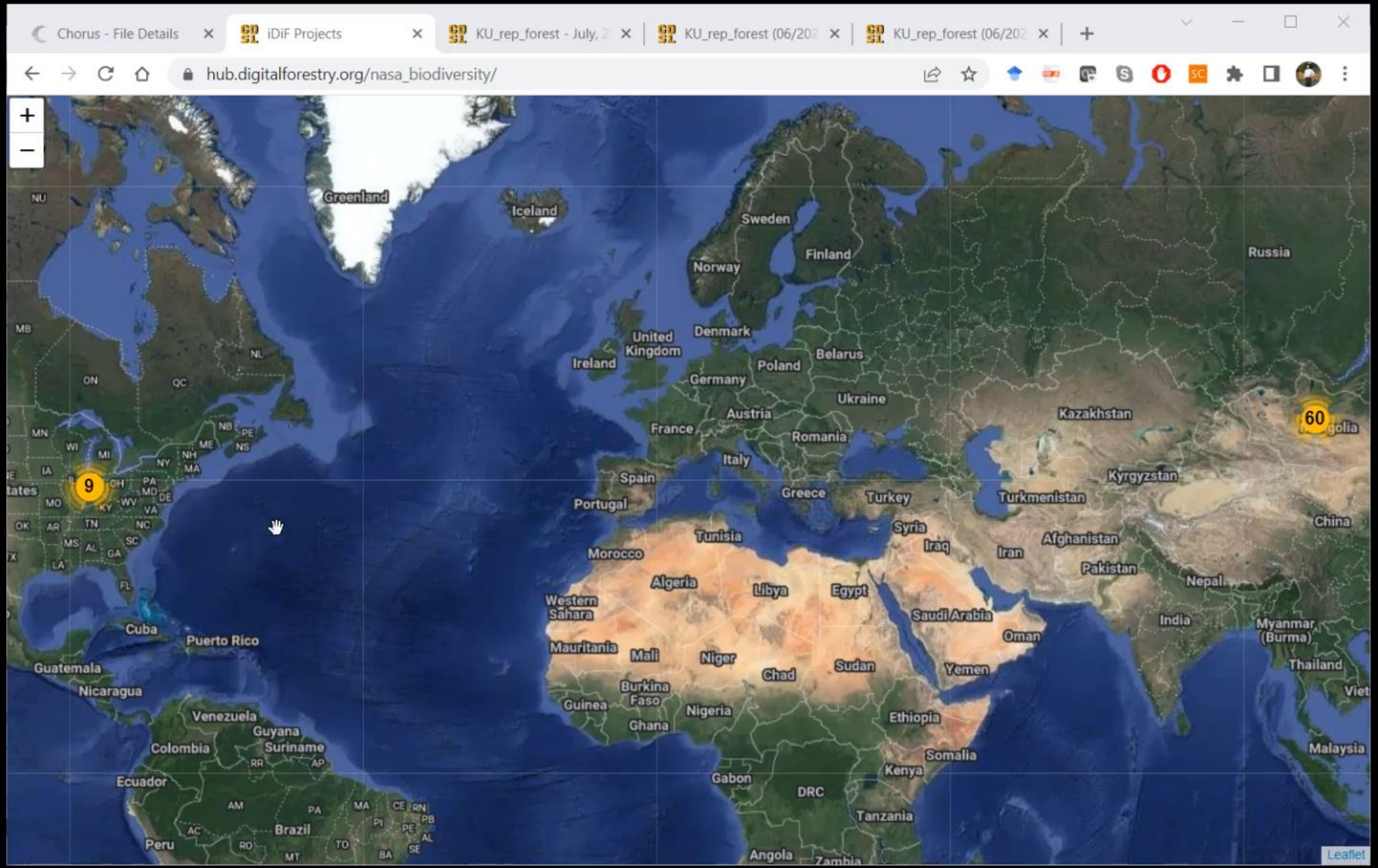

Data Collection Completed

	Disturbance Acoustic Sensors	Acoustic Indices	Sound Source Surveys	Sound Labeling	Plant Surveys	UAS Mapping	GEDI Mapping	ECOSTRESS Mapping	MODIS EVI Mapping
Tippecanoe Indiana	Done	Done & In Progress	Done	Start Sept 14	Done	Done	Started	Started	Started
Arkhangai, Mongolia	Done	Done & In Progress	Done	Start Sept 14	Done	Done	Started	Start Nov 15	Start Nov 15
Issa Valley, Tanzania	Start Oct 1	Done & In Progress	Start Oct 1	Start Jan 15	Start Jan 1	Start Oct 1	Start Oct 1	Start Nov 15	Done & In Progress
Sundarbans, Bangladesh	Start Nov 15	Done & In Progress	Start Nov 15	Start Jan 15	Done	Start Nov 15	Start Nov 15	Start Nov 15	Start Nov 15

Data Collection – Done & In Progress

	Disturbance Acoustic Sensors	Acoustic Indices	Sound Source Surveys	Sound Labeling	Plant Surveys	UAS Mapping	GEDI Mapping	ECOSTRESS Mapping	MODIS EVI Mapping
Tippecanoe Indiana	Done	Done & In Progress	Done	Start Sept 14	Done	Done	Started	Started	Started
Arkhangai, Mongolia	Done	Done & In Progress	Done	Start Sept 14	Done	Done	Started	Start Nov 15	Start Nov 15
Issa Valley, Tanzania	Start Oct 1	Done & In Progress	Start Oct 1	Start Jan 15	Start Jan 1	Start Oct 1	Start Oct 1	Start Nov 15	Done & In Progress
Sundarbans, Bangladesh	Start Nov 15	Done & In Progress	Start Nov 15	Start Jan 15	Done	Start Nov 15	Start Nov 15	Start Nov 15	Start Nov 15

Data Collection – Recently Launched

	Disturbance Acoustic Sensors	Acoustic Indices	Sound Source Surveys	Sound Labeling	Plant Surveys	UAS Mapping	GEDI Mapping	ECOSTRESS Mapping	MODIS EVI Mapping
Tippecanoe Indiana	Done	Done & In Progress	Done	Start Sept 14	Done	Done	Started	Started	Started
Arkhangai, Mongolia	Done	Done & In Progress	Done	Start Sept 14	Done	Done	Started	Start Nov 15	Start Nov 15
Issa Valley, Tanzania	Start Oct 1	Done & In Progress	Start Oct 1	Start Jan 15	Start Jan 1	Start Oct 1	Start Oct 1	Start Nov 15	Done & In Progress
Sundarbans, Bangladesh	Start Nov 15	Done & In Progress	Start Nov 15	Start Jan 15	Done	Start Nov 15	Start Nov 15	Start Nov 15	Start Nov 15

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- Fulbright Program