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SALVE Project
In Bochum

# The Use of ArcGIS for Data Collection and Sample Charactarization of the Urban Acoustic Environment

## The example in SALVE

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# Background on the Pilot Project SALVE

- In health research, health policy, and spatial planning the focus is limited to noise

- The acoustic environment below the ‘noise’ threshold is not fully investigated
  - opportunity for frequency and sound composition investigations related to cities and health

- Relationship between the built and acoustic environment and health of interest to spatial planning and epidemiology

# Aims of the Pilot Project SALVE

SALVE Project

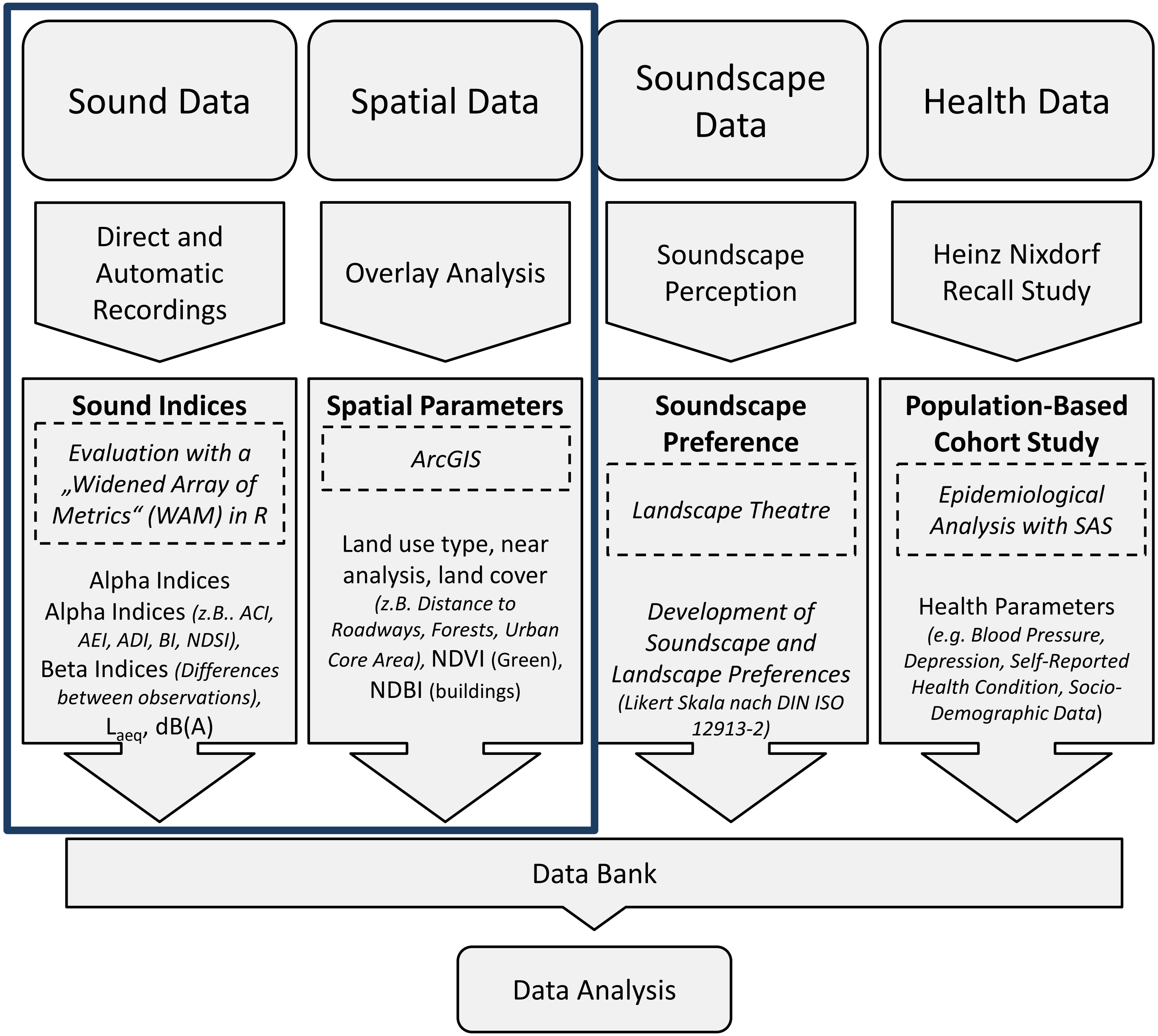
1. Measurements of different acoustic environments in Bochum, Germany under consideration of spatial-temporal structures (landuse, season, time of day) - focus on human habitation

   - *Broaden automated and comprehensive procedures for the classification of sound data (dB, Hz, time) into indices (metrics)*

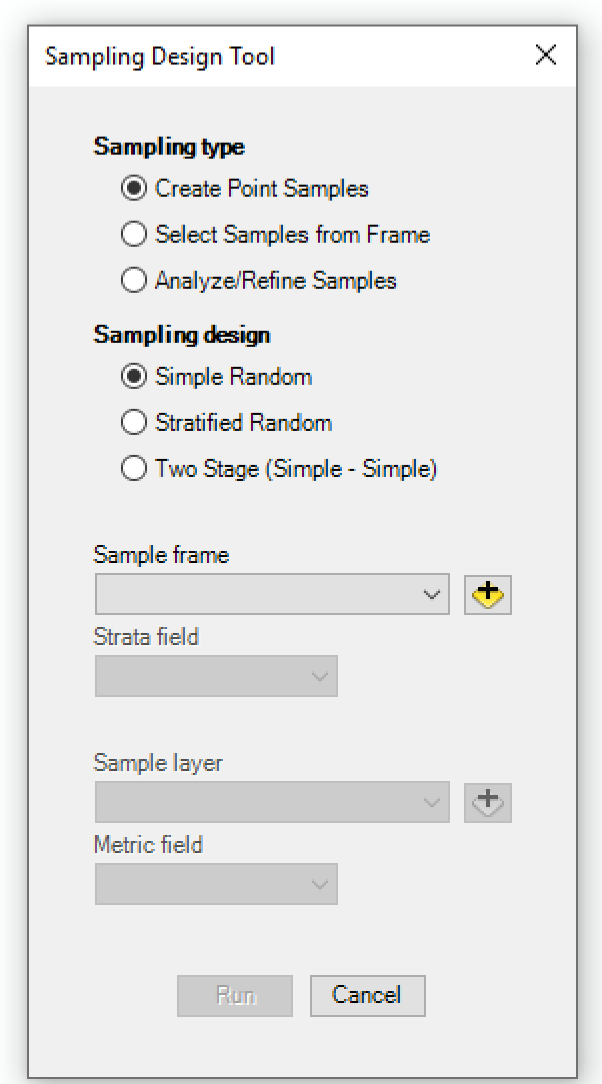
2. Analysis of associations between sound indices, spatial structure and health in a population cohort (HNR)
3. Survey to determine soundscape and landscape preferences, together

**Interdisciplinary Research Field**
***Healthy Urban Soundscapes***

# SALVE Data Structure



# Sample Design – Bochum, Germany



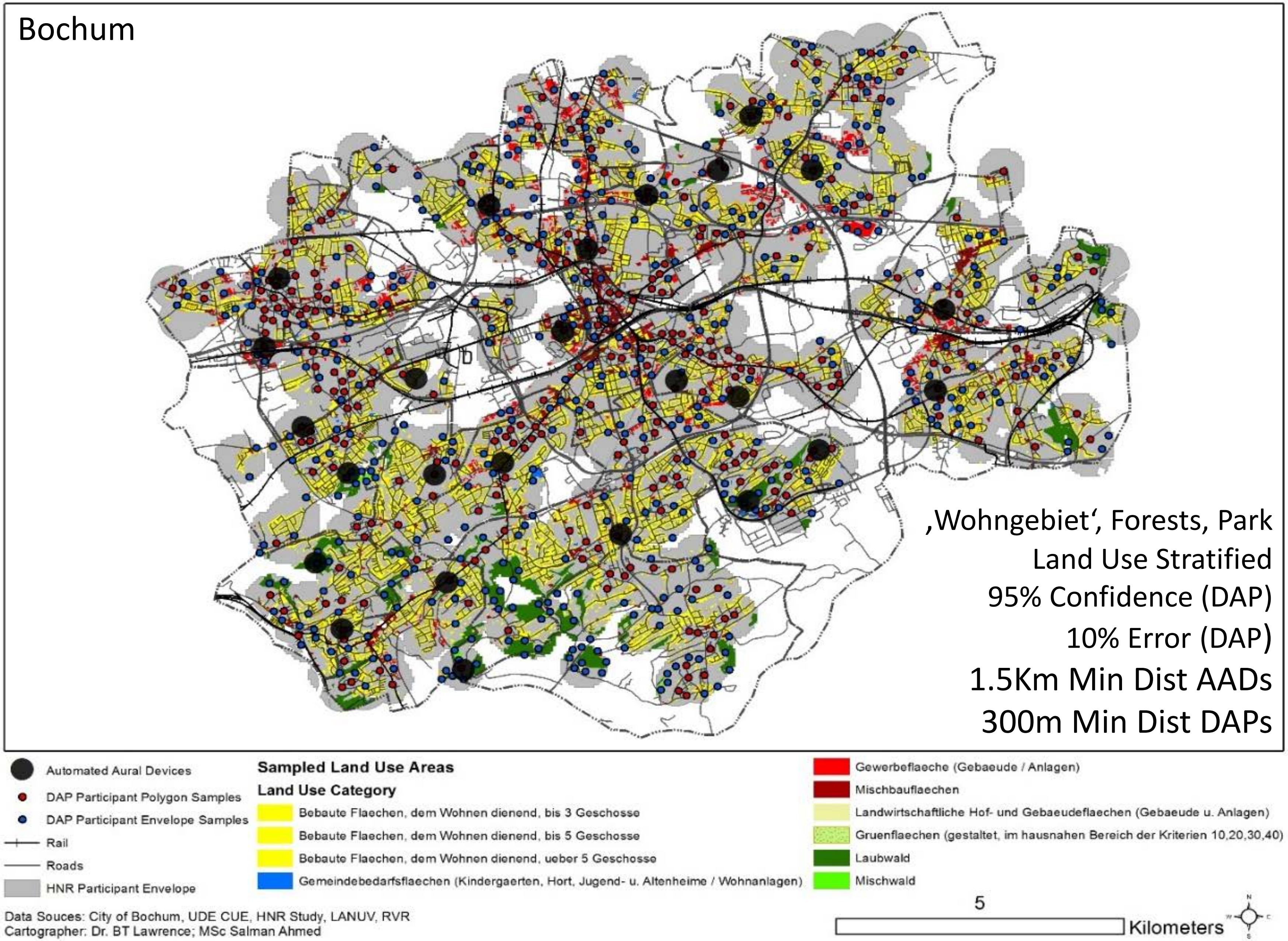

NCCOS NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

***Sample Design Tool Add-In***

1. *Spatial sampling*
2. *Scalable data requirements*
3. *Random selection*
4. *Multiple sampling designs*: Simple, stratified, and two-stage sampling designs.
5. *Sample unit-based sampling*: Points or polygons are selected from a sample frame.
6. *Area-based sampling*: Random points are generated within a polygon.
7. *Analysis*: set sample sizes; allocate samples among strata.
8. *Computations*: Mean, standard error, and confidence intervals
9. *Output*: Geographic positions; sample size estimates; sample statistics

*Source: https://coastalscience.noaa.gov/project/sampling-design-tool-arcgis/*

# Sample Design – Bochum, Germany



# Direct Sampling – Networked Clusters

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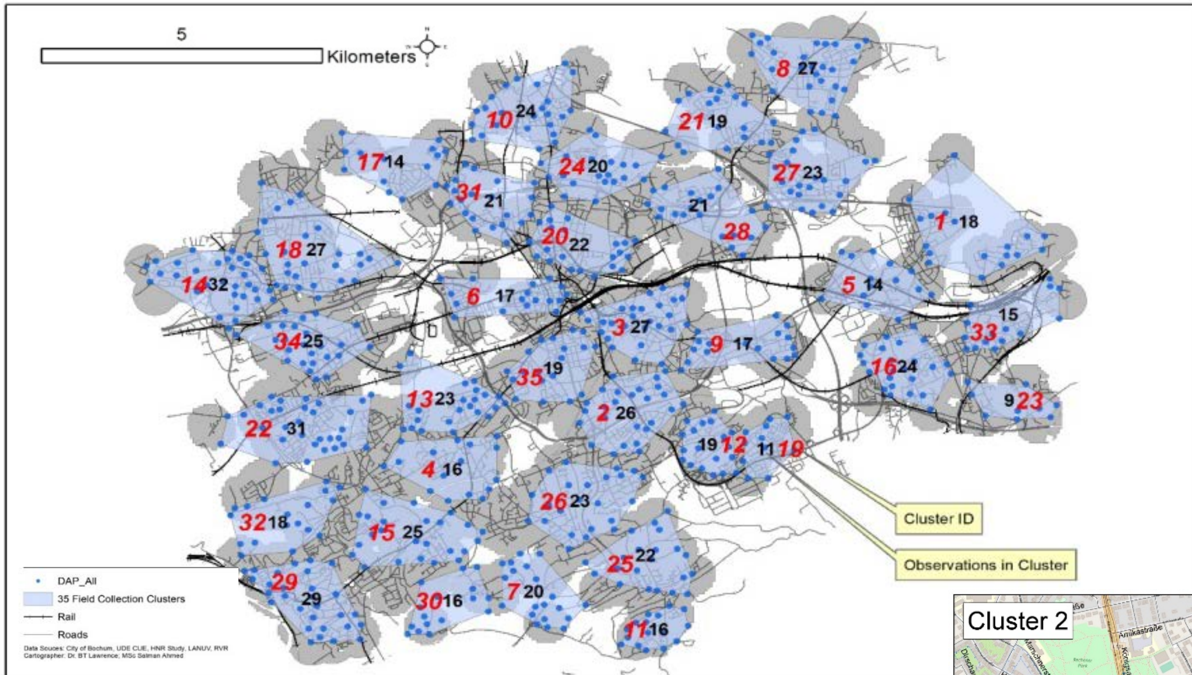



## Grouping Analysis in ArcGIS

>Spatial Statistics

>Mapping Clusters

*K=20 Nearest Neighbors Alg.*

## Minimum Bounding Geom.

>Data Management

>Features

*Convex Hull*

## Network Analyst

>Network Dataset (B.Rds)

>Distance Field

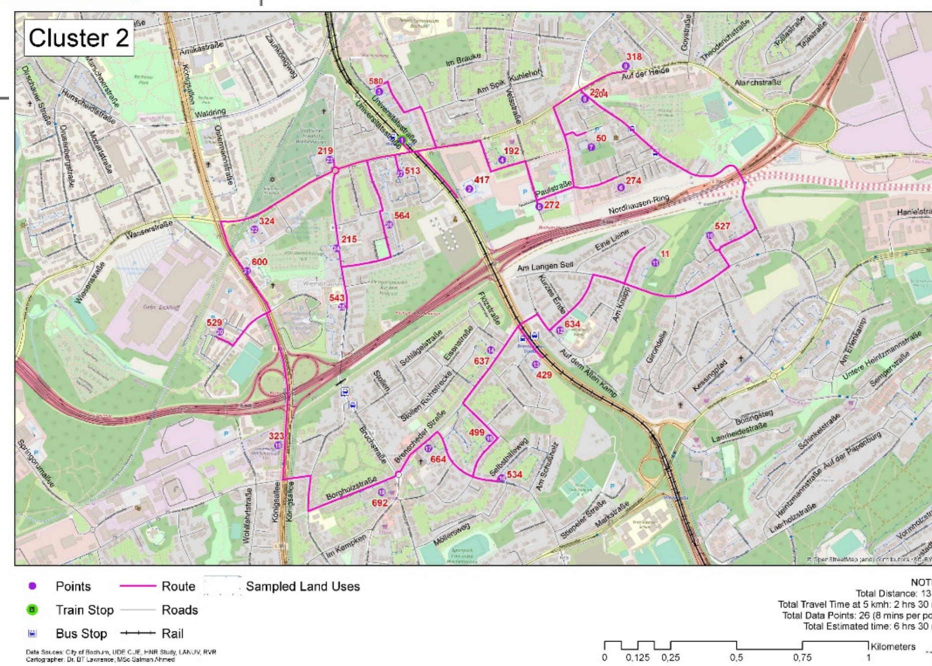
>Time Field

> 500m Prox.

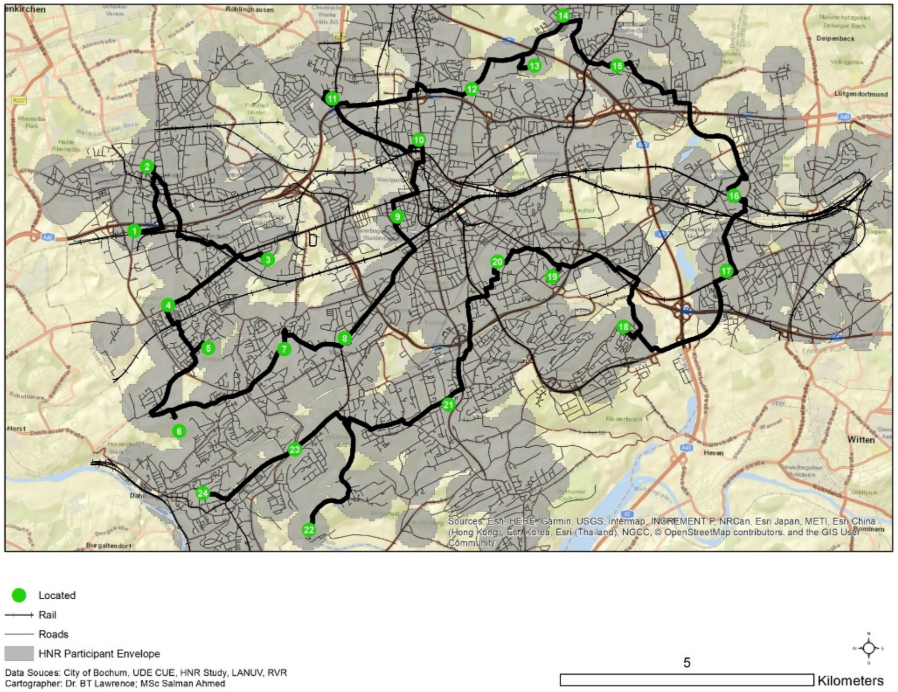
>Two-Way Travel Allowed

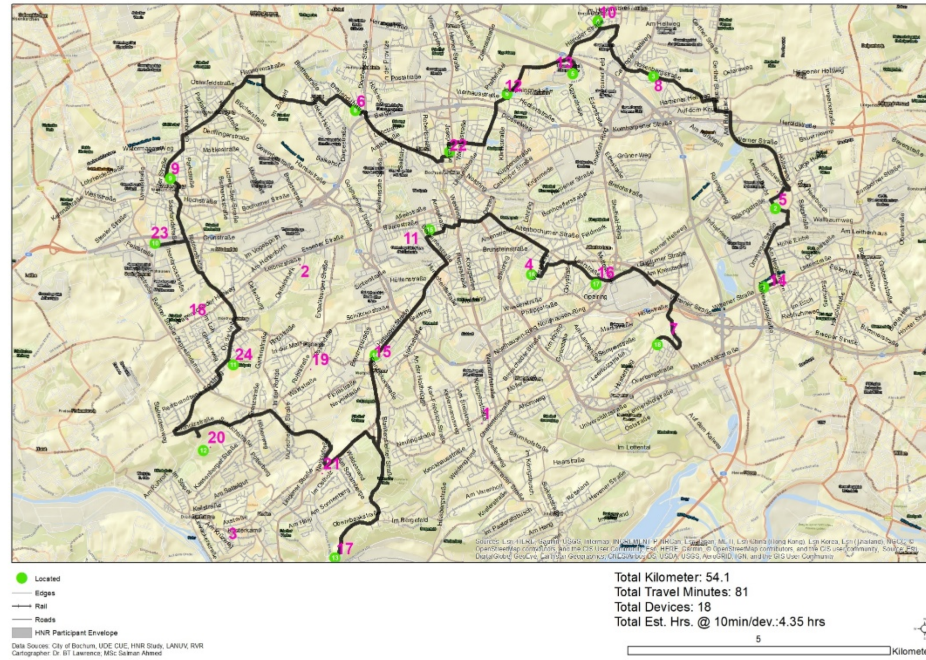
## Manpower Estimate

NOTES:
Total Distance: 13 km
Total Travel Time at 5 kmh: 2 hrs 30 min
Total Data Points: 26 (8 mins per point)
Total Estimated time: 6 hrs 30 min

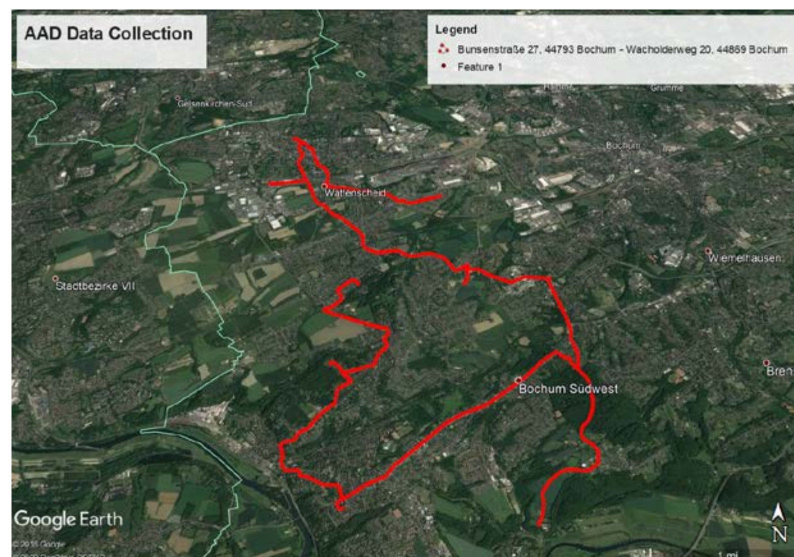


# Automated Device Data Harvest




Network Analyst affords a flexible and open access approach to extensive long-term and geographically complex field data collection.



# Summary of Collected Data

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| Device | Sample Points | Sample Days per year | Measurement Time (in min.) | Total recorded time (in min.) |
|---|---|---|---|---|
| Manual (DAP) | 730 | 4 | 5 | 14 600 |
| Automated (AAP) | 24 | 48 x 365 | 3 | 1 261 440 |
| Binaural (BR) | 24 | 8 | 3 | 576 |

**1 276 616 min ≙ 21 276 hours ≙ 886 days (equiv.) of audible sound data collected in Bochum**

# Widened Array of Metrics (WAM)

SALVE Project

**Formative Topical Development (2016-2018)**

- Advanced Planning Studios at TU Dortmund and University of Duisburg Essen
- *R Studio; Soundscape Ecology*

**Rapid Systematic Literature Review in Context of SALVE (2018)**

- Ten year search of ScienceDirect and The Journal of the Acoustical Society of America
- Keywords: *Sound, Soundscape, Acoustic, Urban, Environment, Ecology, Metric, Index;*
- Boolean (AND, OR, NOT)
- N= 1,142

**Screening, Review, Final Selection (2018-2019)**

- Screening for
  - English
  - Metrics or indices with dB, Hz and time
- Literature - N=57; N=17
- *43 Potential Metrics*
- ***WAM = 33-34 Alpha, Beta, dB Metrics***

# WAM Overview of Findings -Alpha

SALVE Project

Table 1 – Alpha and beta sound indices, their origin and calculation package in R

| Index | Abb. | Principle | Reference | Calculation Package |
|---|---|---|---|---|
| Bioacoustic Index | Bio | Biophony Level | 19 | soundecology |
| Amplitude Index | M() | Median of Amplitude Envelope | 20 | Seewave |
| Temporal Entropy | $H_t$ | Envelope Complexity | 21 | Seewave |
| Acoustic Richness | AR | Envelope Complexity and Intensity | 20 | Seewave |
| Spectral Entropy | $H_f$ | Spectrum Complexity | 21 | Seewave |
| Acoustic Entropy Index | H | Envelope and Spectrum Complexity | 21 | Seewave |
| Acoustic Diversity Index | ADI | Spectrum Complexity | 22 | soundecology |
| Acoustic Evenness Index | AEI | Envelope and Spectrum Complexity | 23 | soundecology |
| Acoustic Complexity Index | ACI | Spectrogram Complexity | 24 | soundecology |
| Number of Peaks | NP | Spectrogram Complexity | 25 | Seewave |
| Normalized Difference Soundscape Index | NDSI | Ratio of Anthrophony to Biophony | 26 | soundecology |
| Shannon's Index | H' | Spectrum Complexity | 26 | Seewave |
| Spectral Persistence | - | Duration of Repeated Clusters | 17, 18 | Kaleidoscope ART 1 |

# WAM - Alpha Scripts in R Studio

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```
# Make sure to first install the soundecology and data.table
packages from CRAN repository

# Load the required packages and libraries
p <- c("parallel", "pracma", "oce", "ineq", "gsw", "seewave",
"soundecology", "data.table", "tuneR", "vegan")
lapply(p, require, character.only = TRUE);

# Set the working directory and retrieve the wave files
oldwd <- getwd()
setwd("C:/SALVE_SoundAnalysis")
files <- dir(pattern = "wav$");

# Prepare the function to calculate eight alpha indices
indices <- function(x){
  x <- readWave(x)
  return(c(sh(meanspec(x, plot=FALSE)),
         acoustic_evenness(x)$aei_left,
         ACI(x),
         acoustic_diversity(x)$adi_left,
         bioacoustic_index(x)$left_area,
         H(x),
         nrow(fpeaks(meanspec(x, plot=TRUE))),
         ndsi(x, fft_w = 512, anthro_min = 1000, anthro_max =
2000, bio_min = 2001, bio_max = 11500)$ndsi_left))};

# Prepare the first object where the results will be written in
n <- length(files)
num <- rep(NA, n)
res <- data.frame(Hf=num, AEI=num, ACI=num, ADI=num,
BIO=num, H=num, NP=num, NDSI=num, row.names=files);

# Run a for loop with the prepared function to calculate the
eight indices for all wav files in the directory
for(i in 1:n) res[i,] <- indices(files[i]);

# Calculate and store the remaining three alpha indices AR, M
and Ht in a second object
ARI <- AR(getwd(), datatype="files");

# Join the three alpha indices from the second object to the first
object containing the rest of the indices
res$M <- ARI$M
res$Ht <- ARI$Ht
res$AR <- ARI$AR;

setDT(res, keep.rownames = "Filename");

# Export all eleven alpha indices to a csv file
write.table(res,
file="C:/SALVE_SoundAnalysis/DAP_Summ_Alpha.csv", sep=" ",
row.names=FALSE)
```

# WAM – Requires Supercomputer



- Alpha and Beta scripts for DAP observations (n=2 920) can be reasonably calculated with a standard well-equiped computer (4 core, 3.5Hz, 16G Ram) in about 48 hours run time
- Alpha and Beta scripts for AAP observations (n=420 480) must be calculated with the LiDo3 super computer at TU Dortmund (360 quad cores, TBs ram); 250+ days with standard well-equiped computer

# WAM – Spring 2019 Prelim. DAP Results

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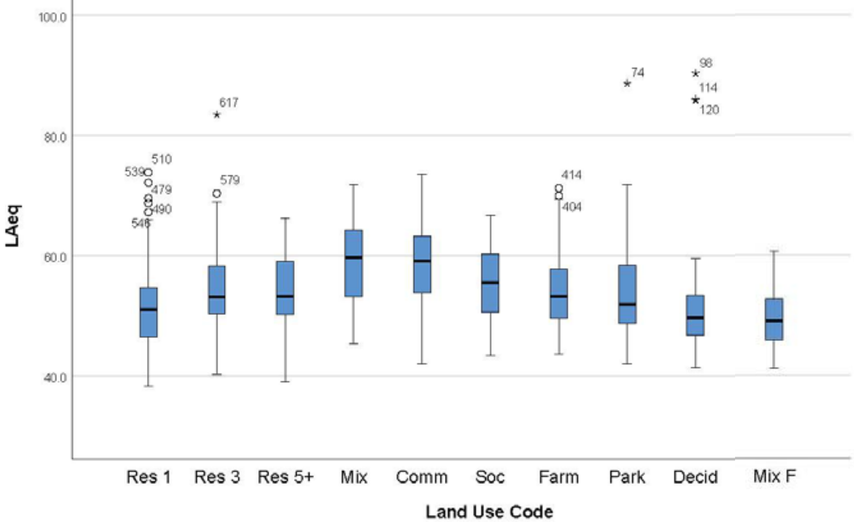
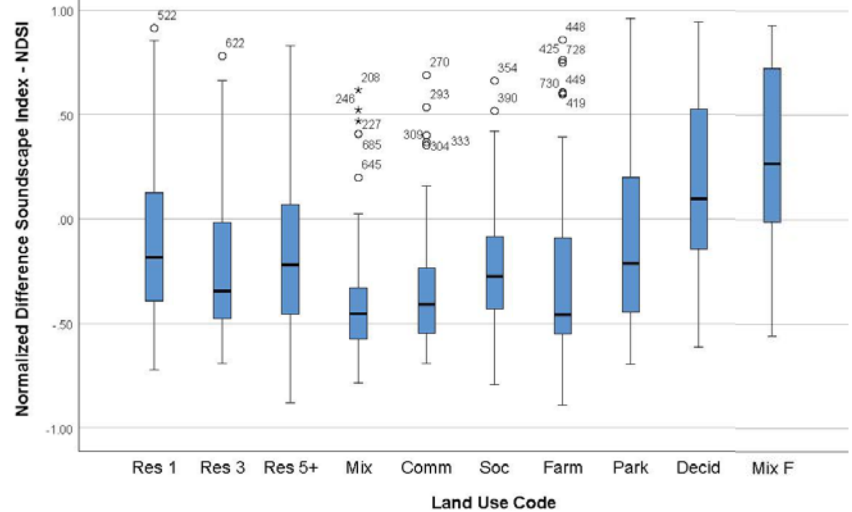
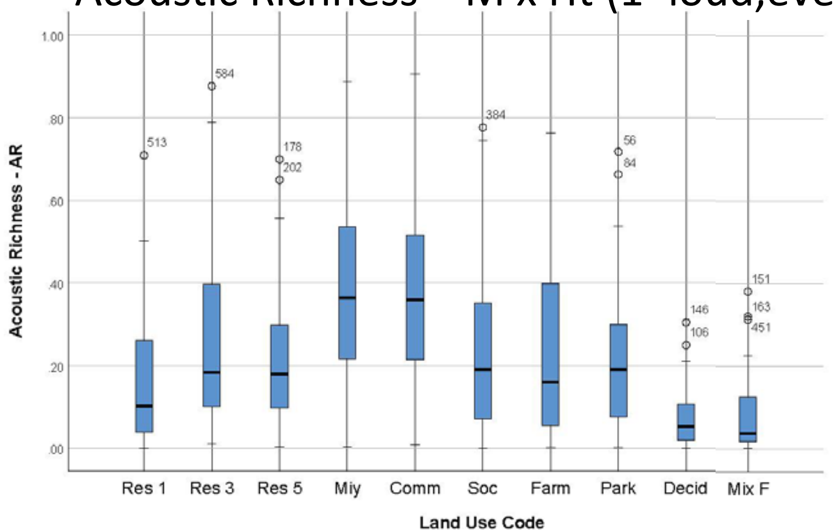
## Decibel Level



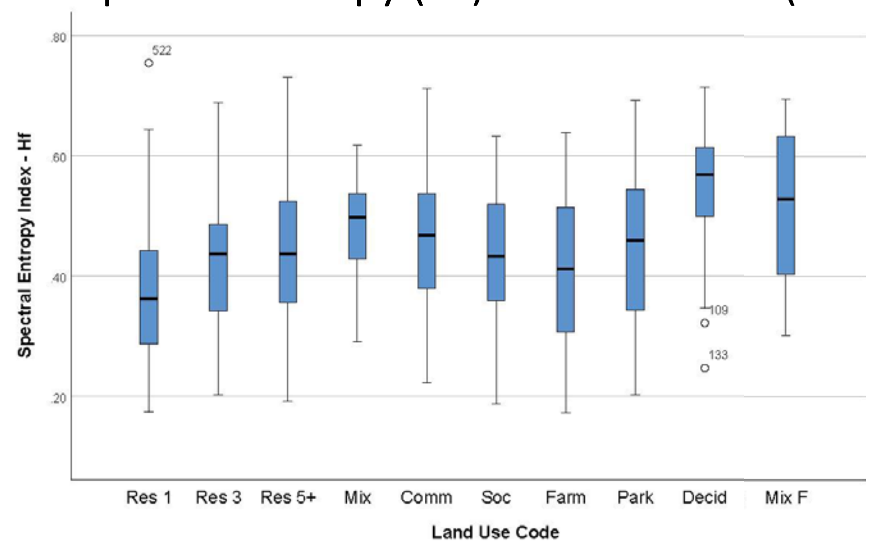

## NDSI – Biophony (1) to Anthrophony (-1)




## Acoustic Richness – M x Ht (1=loud,even)




## Spectral Entropy (Hf) – Hz Evenness (1=even)



# Interpolated ‚Sound Surfaces'

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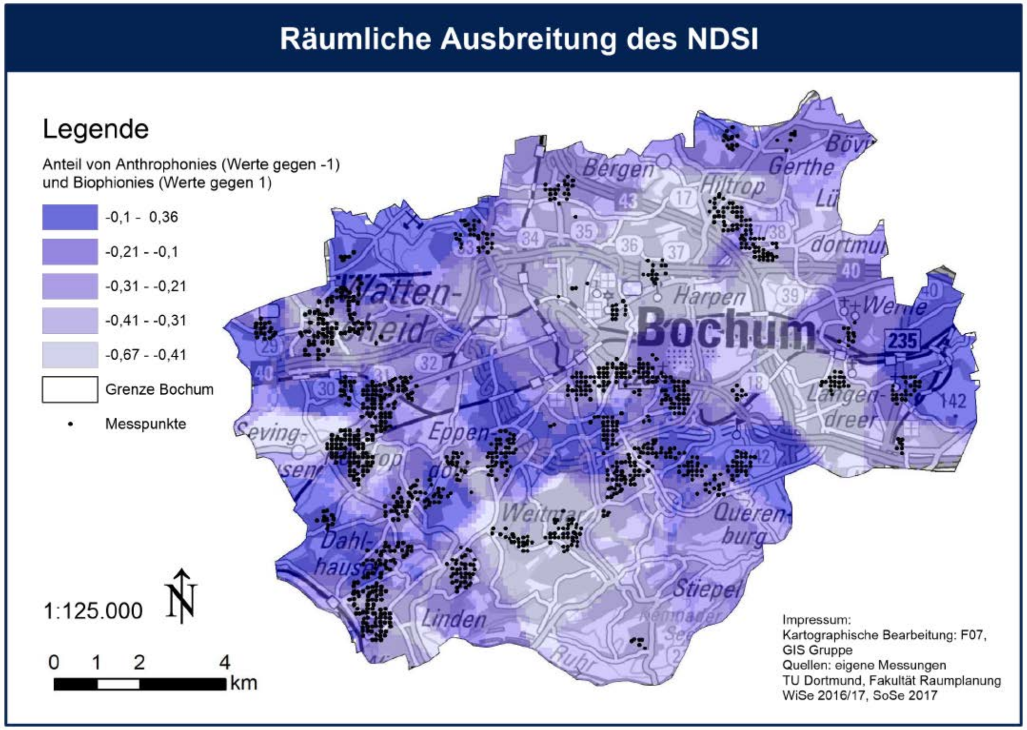


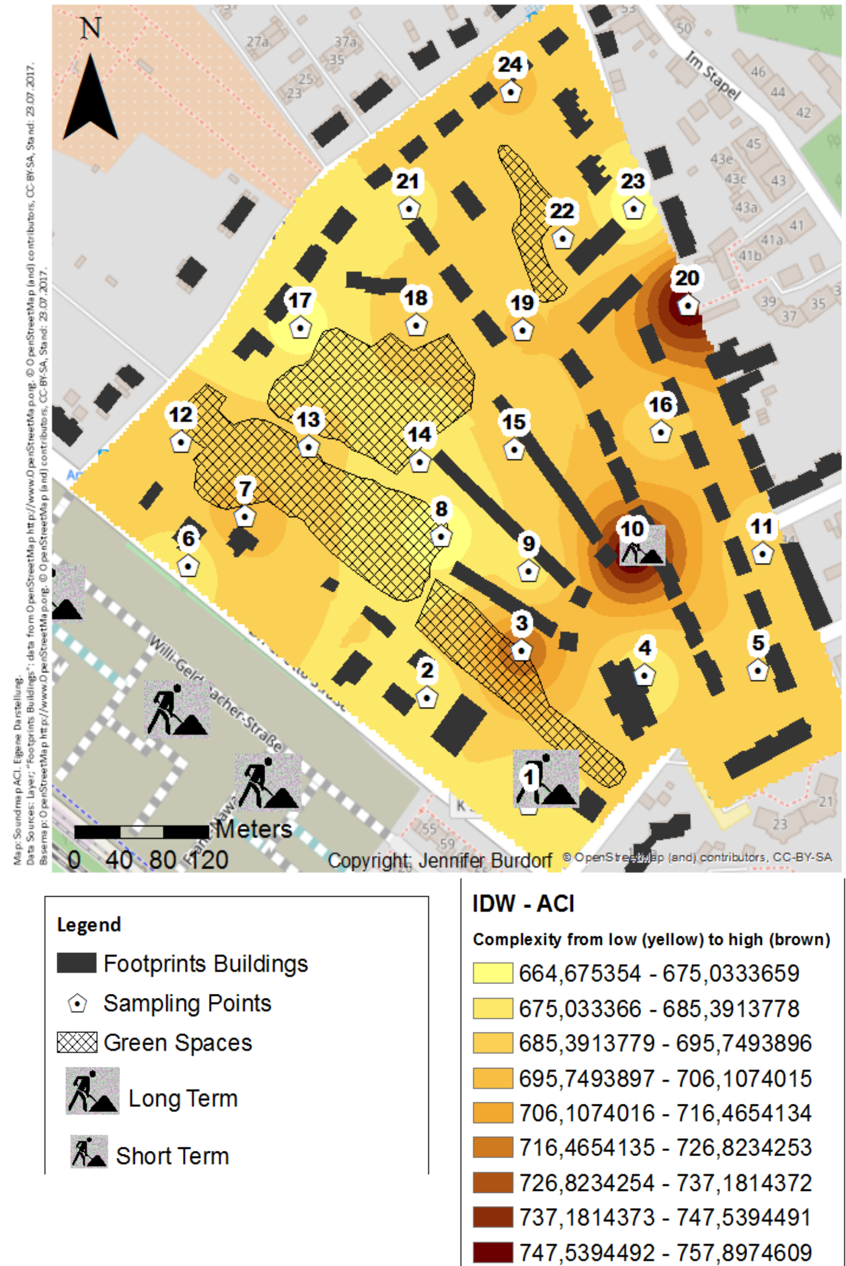


Interpolation

> Natural Neighbor

> Inverse Distance Weighting

City and Neighborhood Scale

> Define Sonotopes

# Spatial Data – Near Analysis, Health Data

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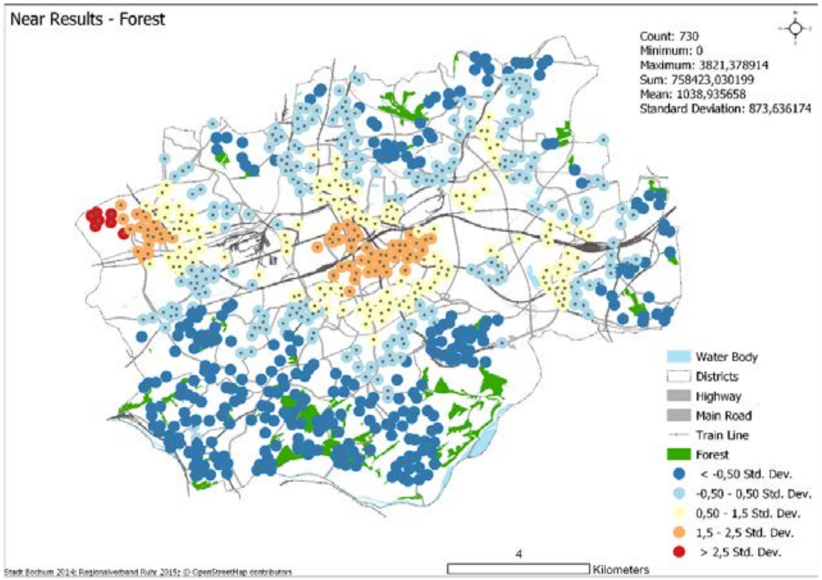
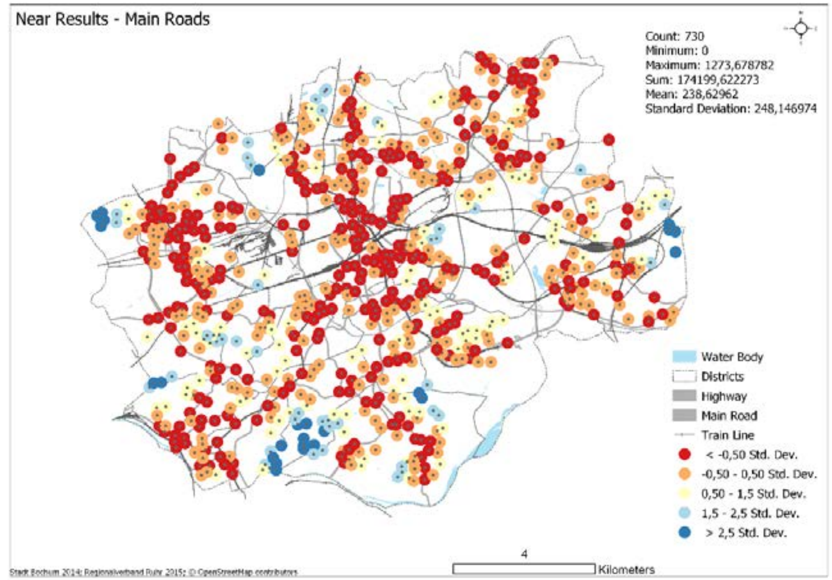
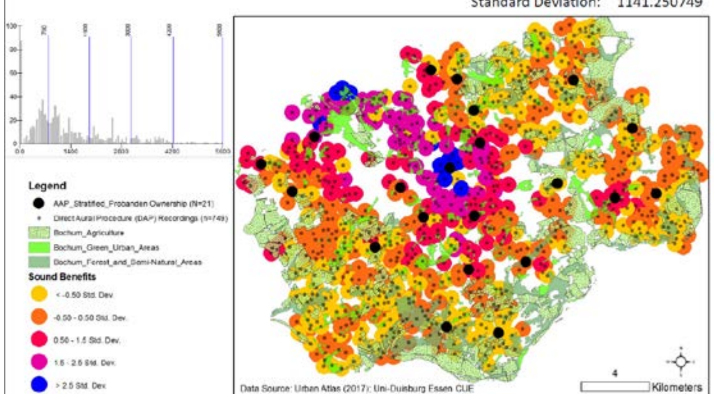



**Near Analysis** > Analysis Tools >Proximity

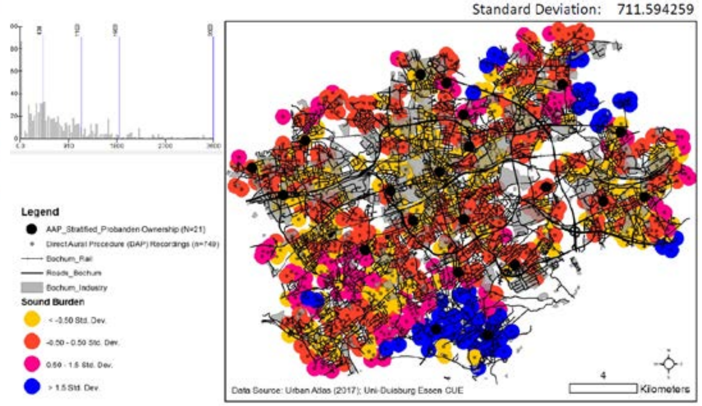
2 Near Results – Sound Benefits

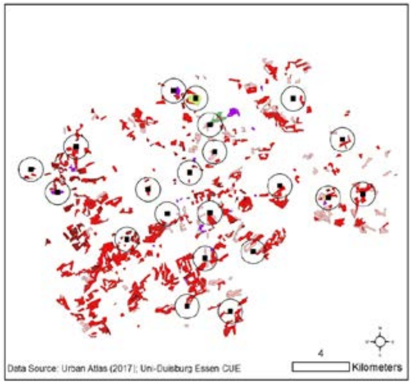
Count: 770
Minimum: 0
Maximum: 5555.910156
Sum: 1027697.402832
Mean: 1334.671952
Standard Deviation: 1141.250749




2 Near Results – Sound Burdens

Count: 770
Minimum: 0
Maximum: 3620.469971
Sum: 601513.842136
Mean: 781.186808
Standard Deviation: 711.594259




Composite Near Indicators – Social & Environmental Justice

Human Health

# Conclusion

SALVE Project

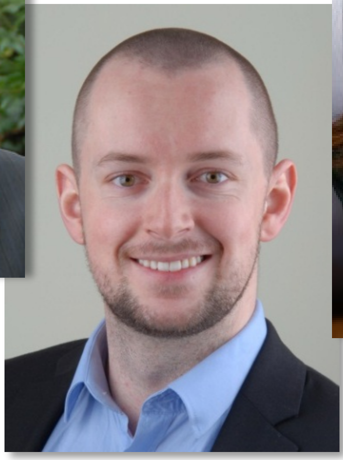
- SALVE levereged several standard spatial analysis methods to develop a defensible sample design strategy for a large set of land uses
- Network analyst helped break down field work into manageable clusters which we designed given personell constraints and is flexible
- Preliminary use indicates WAM may provide a broader understanding of the urban sound environment than decibel focused indices alone
- Spatial datasets including near analyisis, NDVI and NDBI will be used to help explain WAM findings in light of spatially distributed health outcomes.

# Thank You !!!

SALVE Project

For further questions, please contact the team….

**Prof. Dr. Dietwald Gruehn**



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