ENV-167

Introduction to environmental engineering

Geographic Information Systems in environmental engineering

Stéphane Joost

Group of Geospatial Molecular Epidemiology (GEOME)

Laboratory for Biological Geochemistry (LGB)

Geospatial Molecular Epidemiology (GEOME) group at LGB

- Geographic Information Systems (GIS)
- Spatial analysis and spatial statistics
- Investigation of genetic and health data in the fields of population genomics and population health
- In population genomics, we participate in the development of the fields of landscape and seascape genomics
- In population health, we carry out research in spatial epidemiology and analyze the geographic dimension of health determinants – with a particular focus on health inequalities – to inform public health authorities

Program

1. Geographic Information Systems for conservation genetics

2. The role of geographic information in spatial epidemiology

Evolutionary biology

Human health, epidemiology

ENV-167

Introduction to environmental engineering

Geographic Information Systems for conservation genetics

Stéphane Joost

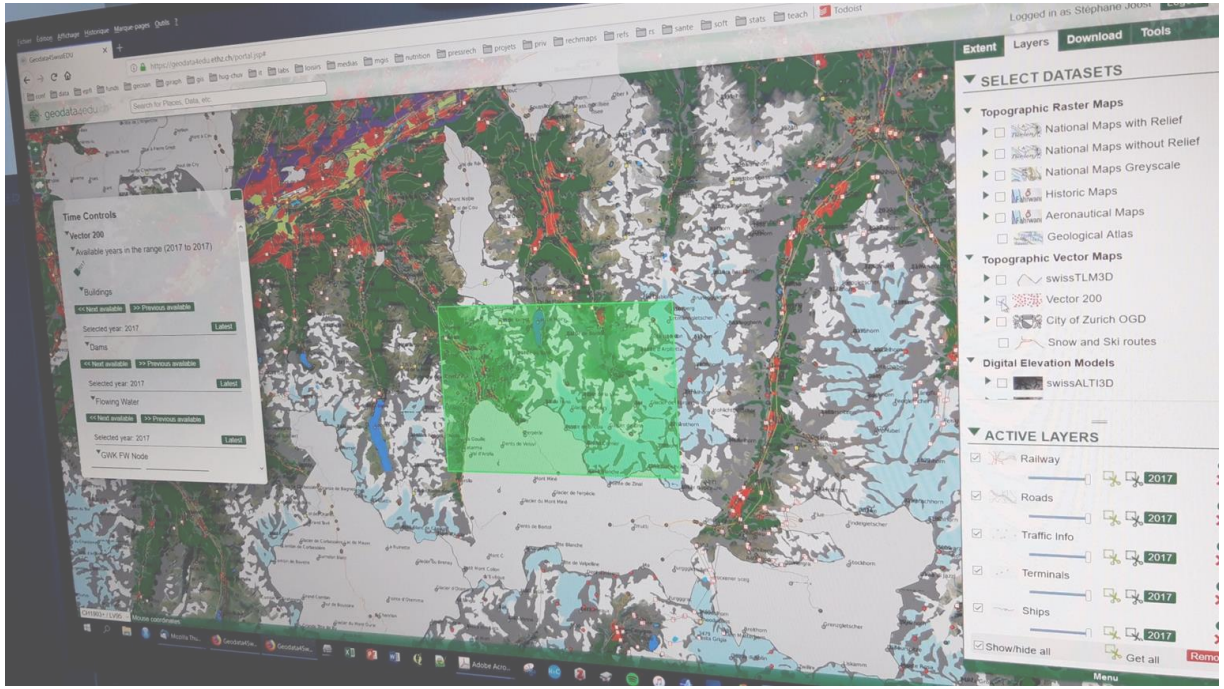
Group of Geospatial Molecular Epidemiology (GEOME)

Laboratory for Biological Geochemistry (LGB)

GIScience and Geographic Information Systems (GIS)

- Geographic Information Science (GIScience) is a scientific discipline at the crossroads of computational science, social science, and natural science
- It studies geographic information, how it represents phenomena in the real world (modeling), how it can be captured, organized, and analyzed in Geographic Information Systems (GIS)
- A GIS consists of integrated computer hardware and software that store, manage, analyze, edit, output, and visualize geographic data (lon x, lat y)
- GIS store geographic information in the two following forms

1. Vector objects described by pairs of geographic coordinates (X,Y) and by a series of thematic attributes (vector mode)
2. Images whose pixels have a given spatial resolution, a center described by a pair of geographic coordinates (X,Y), and a thematic attribute (raster mode)



- Geographic data are stored in a spatial database and can be visualized on a cartographic interface

GIS for biodiversity conservation

GIS are of interest to the domain of conservation biology because they can contribute to:

1. The elaboration of efficient decision-making support approaches to favor the conservation of plant/animal genetic diversity
2. The advancement of our understanding of the mechanisms controlling the evolution of species (adaptation to the local environment)

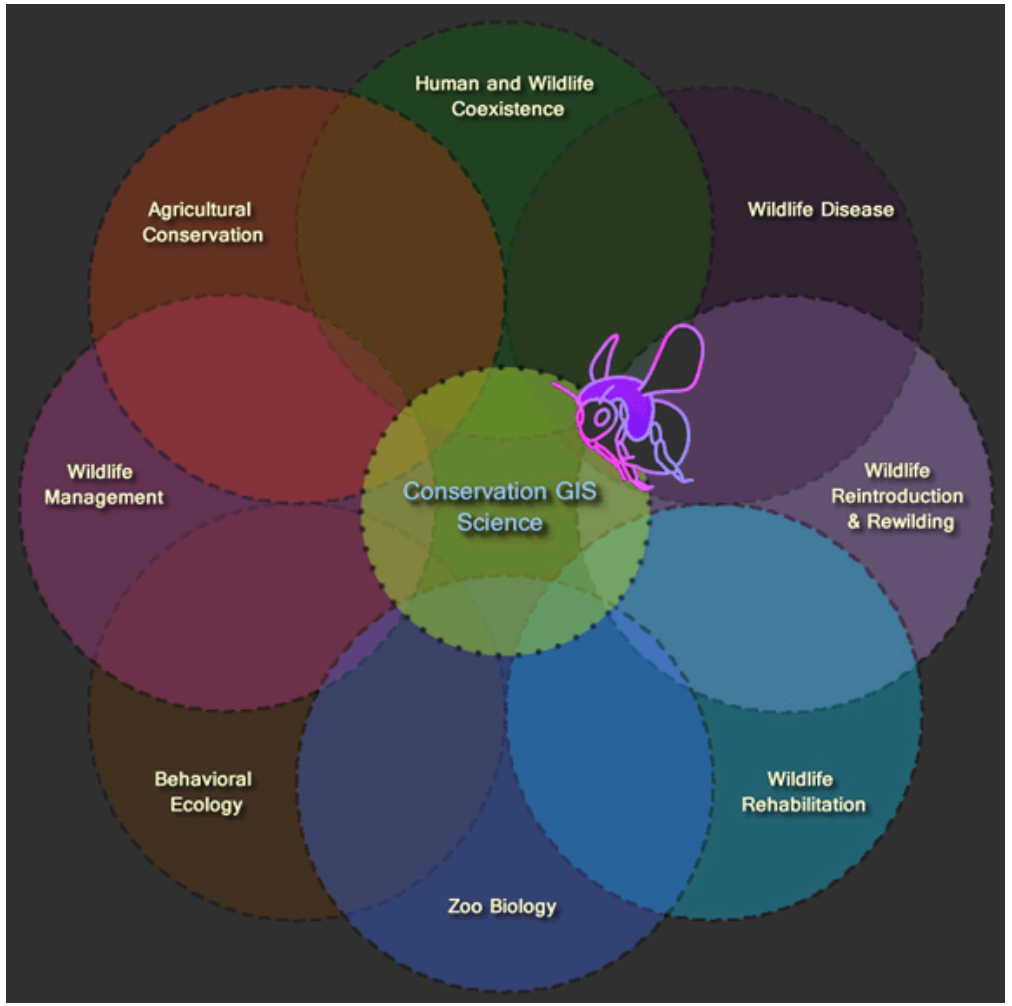
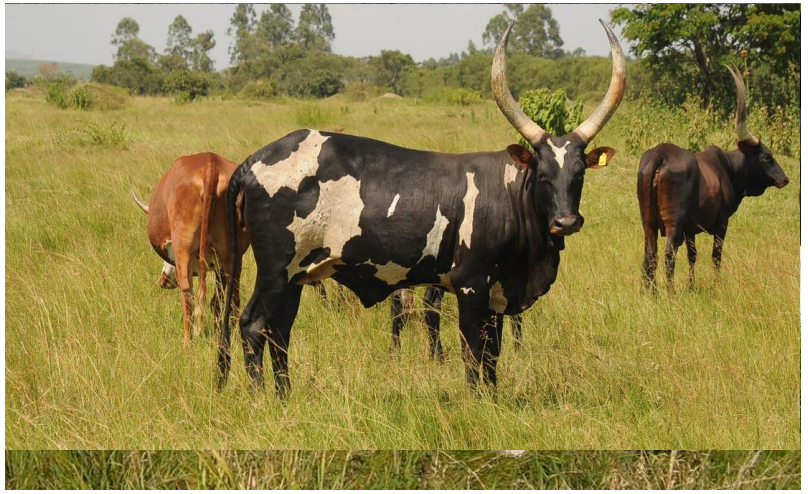


Figure: Sandoval-Green, C.M. J. «GIS as cross-pollinator»

Conservation of Farm Animal Genetic Resources (FAnGR)

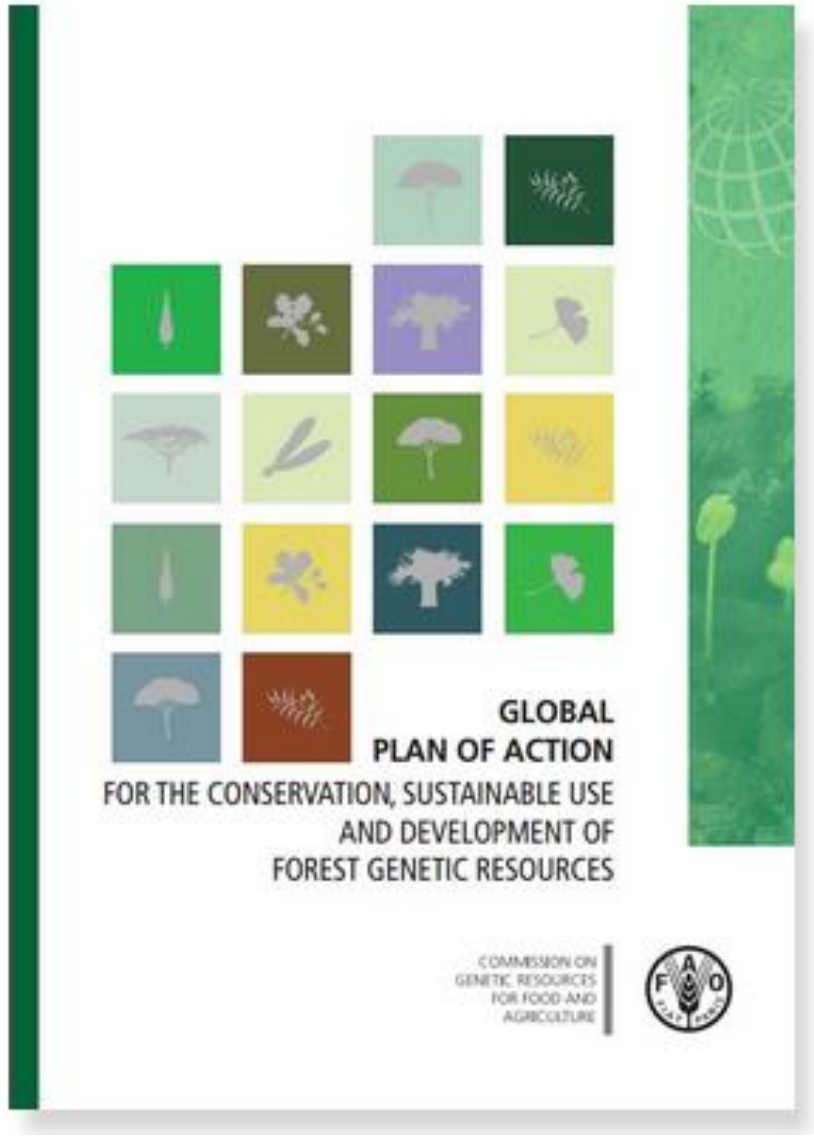
- Valuable livestock breeds possess valuable genetic resources
- Valuable breed = unique, robust, able to adapt to specific environmental conditions (hot, cold, humid, etc.)
- Valuable gene = unique gene conferring a selective advantage (e.g. disease resistance, adaptation to cold)
- For productivity purposes, breeders tend to choose highly productive breeds, that are not adapted to local conditions
- Crossbreeding of locally adapted animals with highly productive imported ones that cannot cope with local harsh environmental conditions and diseases
- The original breed is **endangered** – biodiversity loss
- Socio-economic issues for the breeders (loose their livelihood, join slums in urban areas)
- Food security, social and biodiversity conservation related issue



FAnGR monitoring Food and Agriculture Organization (FAO), United Nations

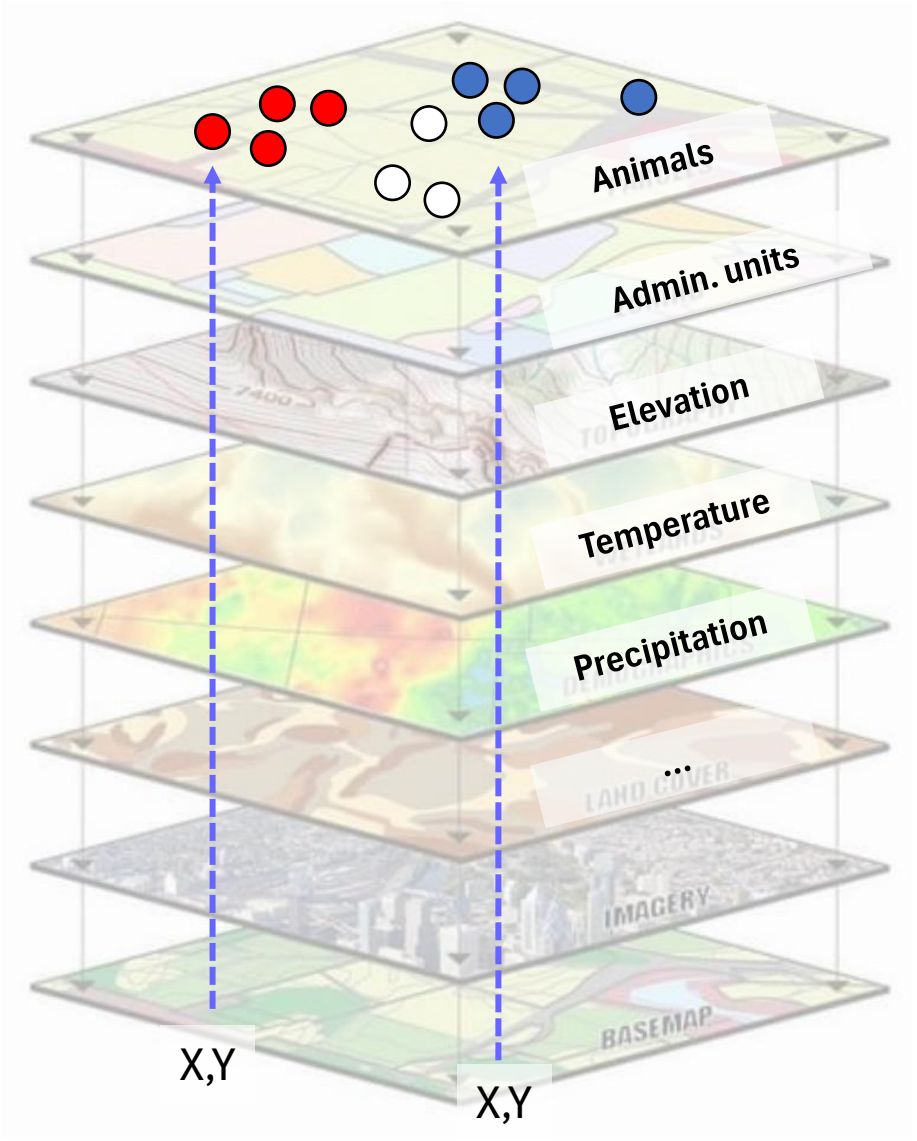
- Since 2007 (Interlaken Conference), FAO's Global plan of action requires member countries to monitor their FAnGR
- In 2016, 17% (1,458) of the world's farm animal breeds were at risk of extinction
- The risk status of many others (58%) was simply unknown due to a lack of data
- 100 livestock breeds have gone extinct between 2000 and 2014

- **Management and conservation of livestock genetic resources** is key: it implies breed prioritization and decision making
- Decision making rests on the simultaneous analysis of several criteria to identify breeds to conserve and to favor sustainable breeding conditions
- Which breeds to prioritize ? How much funds allocated?
- Need for georeferenced data from different fields



Data categories

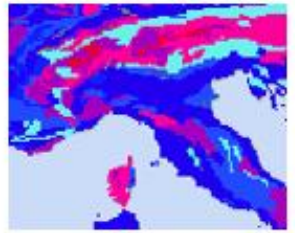
1. **Genetics** - Population and evolutionary genetics
2. **Animal husbandry** practices
3. **Socio-economics** and **socio-demographics** in the regions where animals are bred
4. **Natural environment**: climatic and geophysical characteristics of the places where animals are bred
5. **Political and administrative boundaries**: geographical units where policies must be applied



GIS and data integration

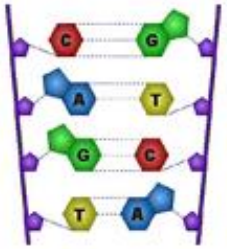
Administrative boundaries
Socio-Economic data
Socio-demographic data

Environmental data:
topography, climate,
soil, etc.



Geographic coordinates
X, Y

GEODATABASE

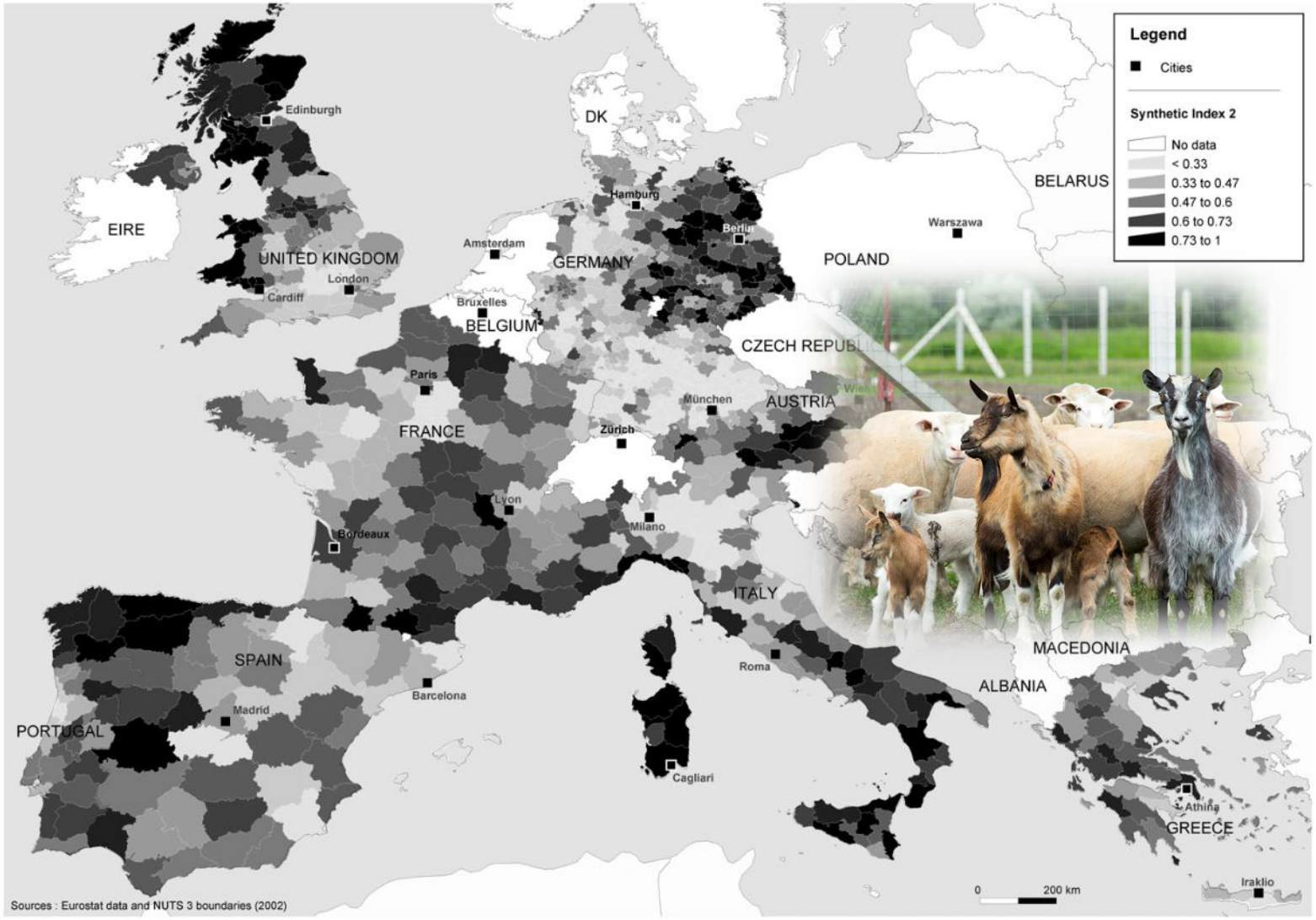


Sampling
Genetic data

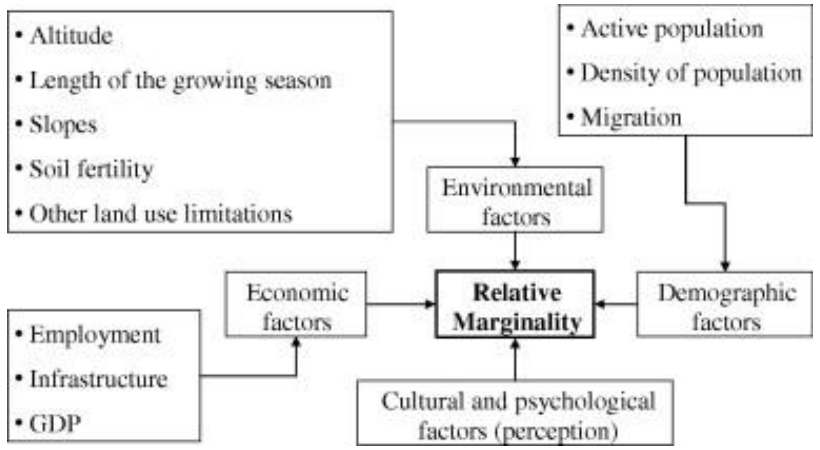
GIS

Questionnaires
Husbandry pratices

Decision-making – Conservation of locally adapted small ruminants



- European project on small ruminants
- Well adapted to marginal areas
- Economic importance
- Marginal area = where land uses are limited because of higher altitude, shorter growing season, steeper slopes, less fertile soils

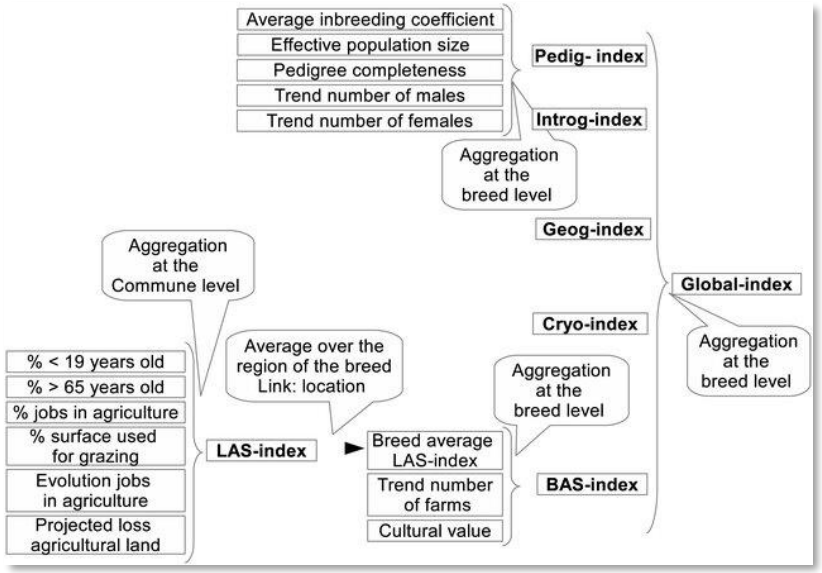


Bertaglia et al. 2007

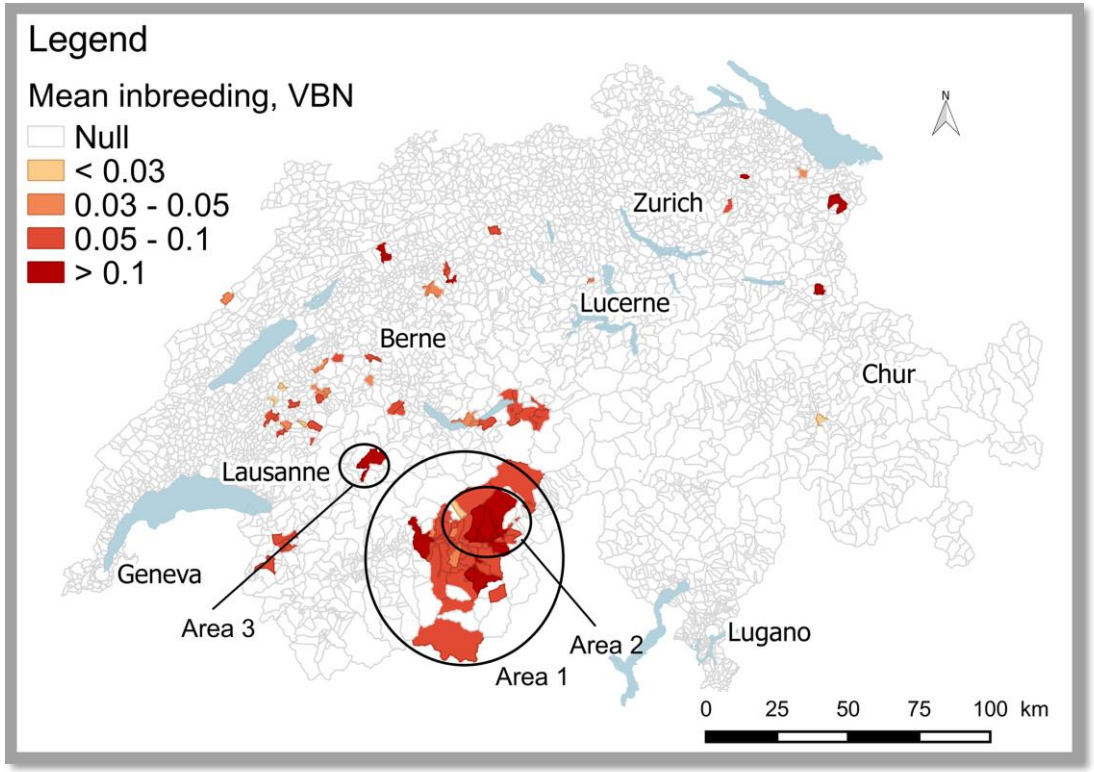
Monitoring of FAnGR

- The status of animal genetic resources is measured through a set of indicators relying on information collected through the FAO **Domestic Animal Diversity Information Sy**stem (DAD-IS)
- Information is compiled by FAO into status and trends of animal genetic resources reports (worldwide), which are produced every two years
- But countries have to develop their own system

Genmon – A WebGIS platform for the monitoring of FAnGR in CH



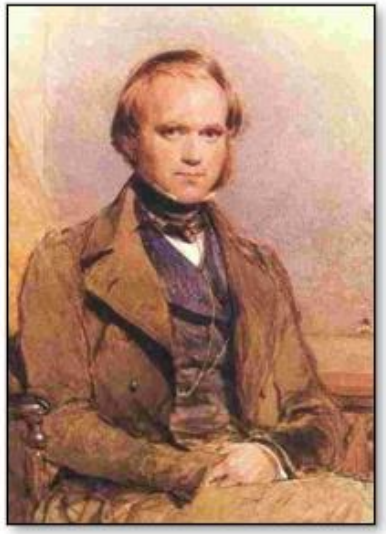
GIS-based Multi-Criteria Decision Analysis (MCDA) approach to support the aggregation of multi-thematic indices



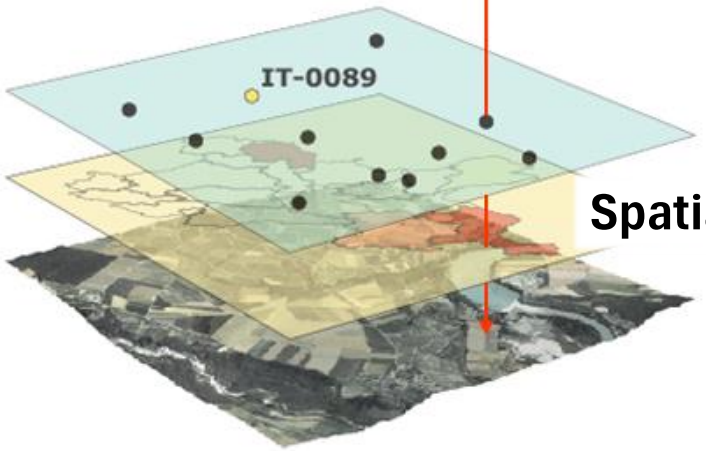
Breed Name	# Animals Last GI	Mean F Last GI	Ne Range	Pedigree completeness	Trend males Last 5 yr	Trend females Last 5 yr	Pedig-Index	Introg-Index	Geog-Index	BAS-Index	Cryo-	Global index
X VBN	34,291	0.101									0B	0.43
FM	26,877	0.067B	50-70B	99.7B	-2.4B	-2.1B	0.41B	0.12B	57.6B	0.64B	0.5B	0.51
SIM	18,301	0.031B	50-70B	85.6B	+54B	+5B	0.5B	0.005B	86.8B	0.54B	0.5B	0.66
OBV	50,632	0.036B	70-500B	99.5B	+2.5B	+4.6B	0.66B	0B	58.3B	0.59B	1B	0.78

Duruz et al. 2017

Understanding of mechanisms controlling the evolution of species



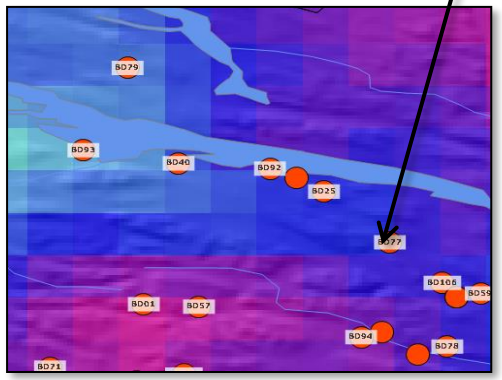
Landscape genomics

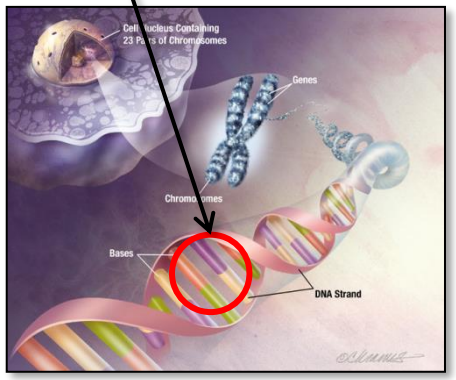


GENETICS

Spatial coincidence

ENVIRONMENT

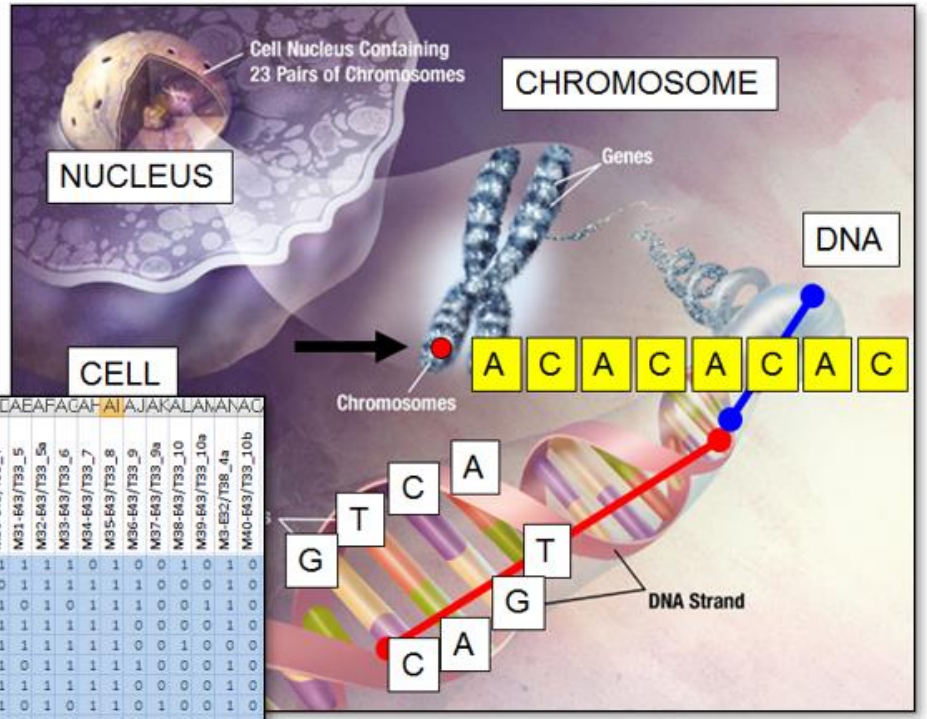




Environmental data ⟷ Genomic data

Association ?

Georeferenced samples – genetic data



GEO

GENETICS

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO
1	farmid	longitude	latitude	ANIMALID	M100-E45/T32_37	M101-E45/T32_38	M102-E45/T32_39	M10-E32/T38_9	M11-E32/T38_10	M12-E32/T38_11	M13-E32/T38_11a	M14-E32/T38_11b	M15-E32/T38_12	M16-E32/T38_13	M17-E32/T38_14	M18-E32/T38_15	M19-E32/T38_17	M1-E32/T38_3a	M20-E32/T38_17a	M21-E32/T38_19	M22-E32/T38_20a	M23-E32/T38_21	M24-E32/T38_21b	M25-E32/T38_22	M26-E32/T38_22a	M27-E43/T33_1	M28-E43/T33_2	M29-E43/T33_3a	M2-E32/T38_4	M30-E43/T33_4	M31-E43/T33_5	M32-E43/T33_5a	M33-E43/T33_6	M34-E43/T33_7	M35-E43/T33_8	M36-E43/T33_9	M37-E43/T33_9a	M38-E43/T33_10	M39-E43/T33_10a	M3-E32/T38_4a	M40-E43/T33_10b
2	PT-0015	-8.2676	41.6848	CHPOBRA3	1	1	1	0	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	1	1	1	1	0	1	0	0	1	0	1	0
3	PT-0022	-7.9273	41.5847	CHPOBRA26	1	1	1	0	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	1	0	1	0	0	0	0	1	1	1	1	1	1	0	0	0	1	0
4	PT-0023	-7.9273	41.5847	CHPOBRA28	1	1	0	0	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	1	0	1	0	0	0	1	0	1	0	1	1	1	0	0	1	1	0
5	PT-0023	-7.9273	41.5847	CHPOBRA29	1	1	1	1	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	1	0
6	PT-0021	-7.8426	41.395	CHPOBRA23	0	0	0	1	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	1	1	1	1	1	1	0	0	1	0	0	0
7	PT-0021	-7.8426	41.395	CHPOBRA25	1	1	1	1	1	1	0	0	0	1	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0	0	0	1	0
8	PT-0017	-7.8269	41.4732	CHPOBRA10	1	1	1	1	1	1	1	0	0	0	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0	1	0
9	PT-0017	-7.8269	41.4732	CHPOBRA11	1	1	0	0	1	1	0	0	0	0	1	0	1	1	0	1	0	1	0	0	0	0	1	0	0	1	0	1	0	1	1	0	1	0	0	1	0
10	PT-0017	-7.8269	41.4732	CHPOBRA12	1	0	0	Na	1	1	0	0	0	0	1	0	1	0	1	0	1	0	0	0	0	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	0
11	PT-0020	-7.8215	41.4235	CHPOBRA21	0	1	0	1	1	1	1	0	0	1	1	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0													
12	PT-0020	-7.8215	41.4235	CHPOBRA22	1	1	0	1	1	1	0	0	0	1	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0	0													
13	PT-0019	-7.7811	41.439	CHPOBRA18	1	1	1	1	1	1	1	0	0	0	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0													
14	PT-0019	-7.7811	41.439	CHPOBRA19	1	1	1	1	1	1	1	0	0	0	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0													
15	PT-0018	-7.78	41.4379	CHPOBRA13	1	1	1	1	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0													
16	PT-0018	-7.78	41.4379	CHPOBRA14	1	1	0	0	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0													
17	PT-0018	-7.78	41.4379	CHPOBRA15	1	1	0	1	1	1	0	0	0	0	1	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0													
18	PT-0016	-7.7291	41.4752	CHPOBRA5	1	1	1	0	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0													
19	PT-0016	-7.7291	41.4752	CHPOBRA6	1	0	0	1	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0													
20	PT-0016	-7.7291	41.4752	CHPOBRA8	1	0	0	1	1	1	0	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0													
21	ES-0060	-6.00263	37.7014	CHSPFLR35	1	0	0	1	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0													
22	ES-0060	-6.00263	37.7014	CHSPFLR37	1	0	0	0	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	1	1	1	0	1	1	1	0	0	0	1	0
23	ES-0060	-6.00263	37.7014	CHSPFLR38	1	1	0	0	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	0	0	0	1	0
24	ES-0060	-6.00263	37.7014	CHSPFLR39	1	1	1	0	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	1	1	0	0
25	ES-0060	-6.00263	37.7014	CHSPFLR40	1	1	0	1	1	1	0	0	0	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0
26	ES-0059	-5.79995	37.9703	CHSPFLR27	1	1	0	0	1	1	1	1	0	0	1	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	0	1	0	1	0
27	ES-0059	-5.79995	37.9703	CHSPFLR28	1	1	0	1	1	1	1	1	0	0	1	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	1	0	0	1	0
28	ES-0059	-5.79995	37.9703	CHSPFLR29	1	1	1	1	1	1	1	1	Na	Na	1	1	0	1	Na	Na	0	1	0	0	0	Na	0	0	0	Na	1	1	1	1	0	1	1	0	0	0	Na	0

LECA Laboratoire d'Ecologie Alpine

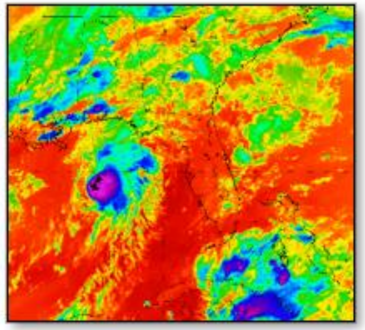
CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD School of Biosciences

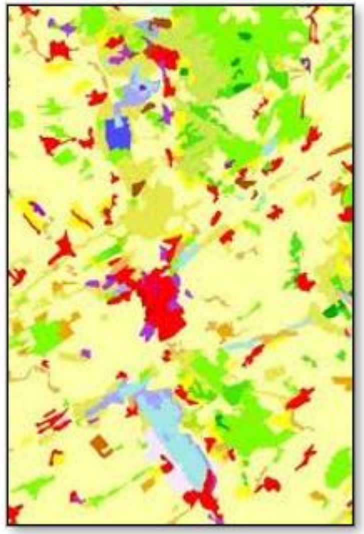
EMBL-EBI European Bioinformatics Institute

Environmental data

GEO | GENETICS | ENVIRONMENT

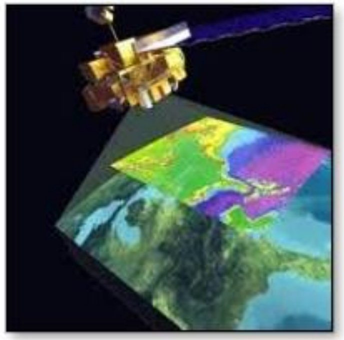
1	farmid	animalid	OARJMP29_allele2_137	OARJMP29_allele2_139	OARJMP29_allele2_141	OARJMP29_allele2_143	OARJM e2_145	OARJM e2_147	OARJM e2_149	OARJM e2_151	OARJM e2_153	OARJM e2_155	OARJM e2_157	OARJMP29_allele2_159	OARJMP29_allele2_161	OARJMP29_allele2_163	OARJMP29_allele2_165	OARJMP29_allele2_167	wndjan	altitude	wndfeb	wndmar	wndapr
1044	PL-4005	OAPLPOM25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.1	22	4.6	5	4.4
1045	PL-4005	OAPLPOM26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.1	22	4.6	5	4.4
1046	PL-4006	OAPLPOM01	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5.3	153	4.8	4.9	4.3
1047	PL-4006	OAPLPOM15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.3	153	4.8	4.9	4.3
1048	PL-4006	OAPLPOM24	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5.3	153	4.8	4.9	4.3
1049	PL-4007	OAPLPOM05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.3	250	4.8	5	4.5
1050	PL-4007	OAPLPOM16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5.3	250	4.8	5	4.5
1051	PL-4008	OAPLPOM09	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5.2	166	4.8	5	4.4
1052	PL-4008	OAPLPOM19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.2	166	4.8	5	4.4
1053	PL-4008	OAPLPOM20	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5.2	166	4.8	5	4.4
1054	PL-4009	OAPLPOM10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5	87	5	5.2	4.6
1055	PL-4009	OAPLPOM21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5	87	5	5.2	4.6
1056	PL-4010	OAPLPOM08	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5.4	208	4.9	5.1	4.5





esa

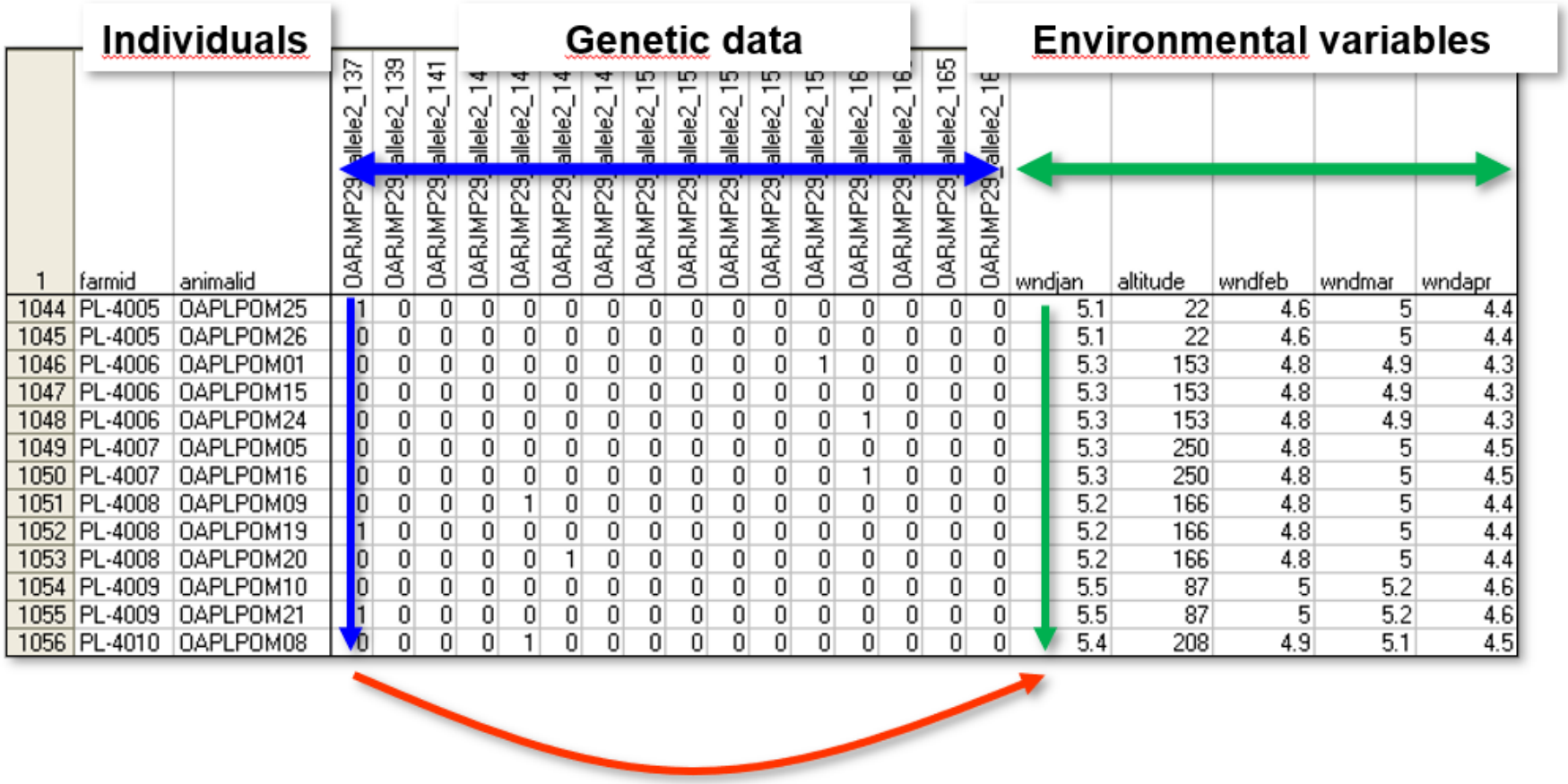
European Environment Agency



CRU

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

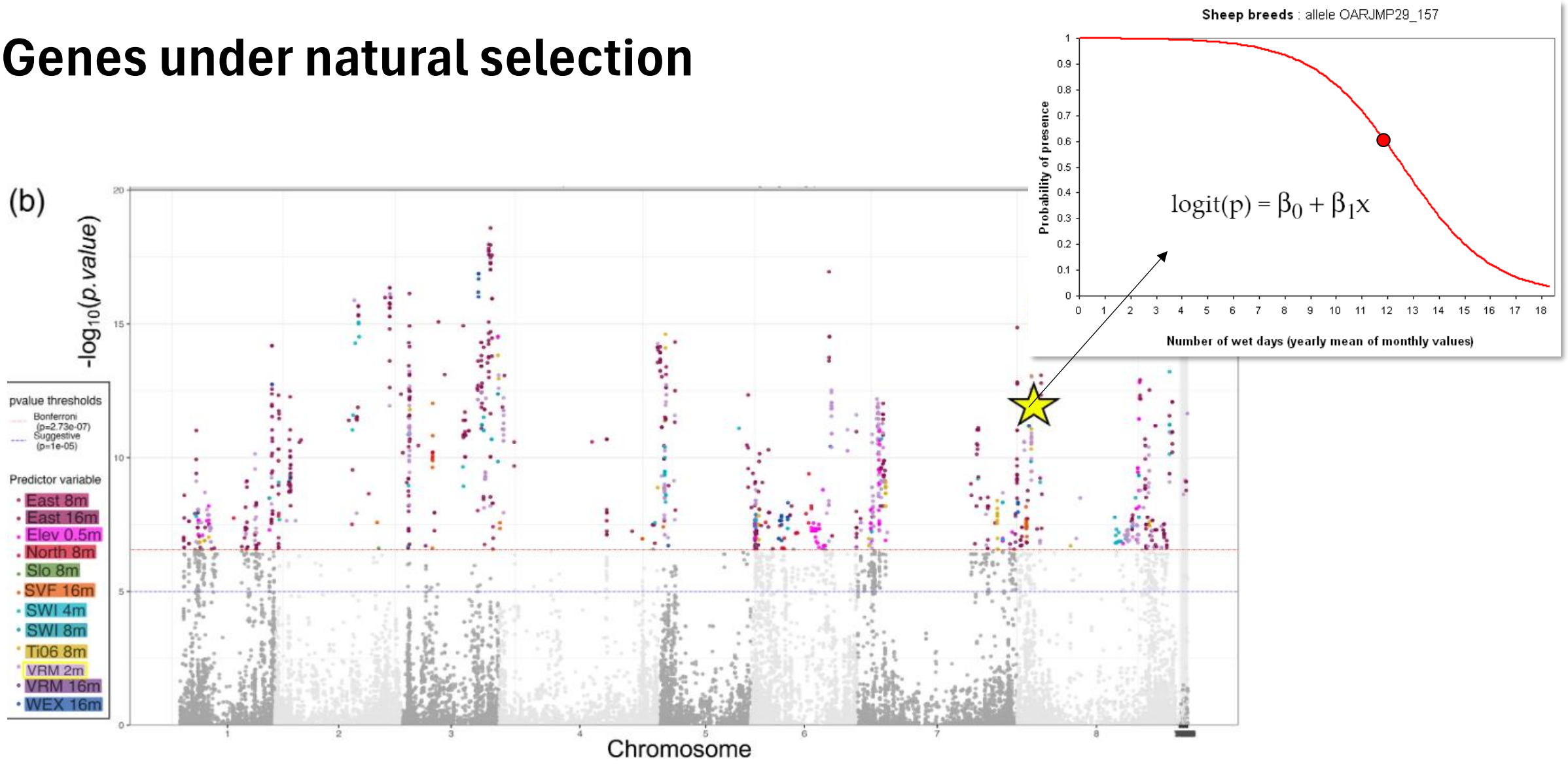
Association models – correlative approach



1	farmid	animalid	OARJMP29_allele2_137	OARJMP29_allele2_139	OARJMP29_allele2_141	OARJMP29_allele2_14	OARJMP29_allele2_14	OARJMP29_allele2_14	OARJMP29_allele2_14	OARJMP29_allele2_15	OARJMP29_allele2_15	OARJMP29_allele2_15	OARJMP29_allele2_15	OARJMP29_allele2_15	OARJMP29_allele2_16	OARJMP29_allele2_16	OARJMP29_allele2_165	OARJMP29_allele2_16	wndjan	altitude	wndfeb	wndmar	wndapr
1044	PL-4005	OAPLPOM25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.1	22	4.6	5	4.4
1045	PL-4005	OAPLPOM26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.1	22	4.6	5	4.4
1046	PL-4006	OAPLPOM01	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5.3	153	4.8	4.9	4.3
1047	PL-4006	OAPLPOM15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.3	153	4.8	4.9	4.3
1048	PL-4006	OAPLPOM24	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5.3	153	4.8	4.9	4.3
1049	PL-4007	OAPLPOM05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.3	250	4.8	5	4.5
1050	PL-4007	OAPLPOM16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5.3	250	4.8	5	4.5
1051	PL-4008	OAPLPOM09	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5.2	166	4.8	5	4.4
1052	PL-4008	OAPLPOM19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.2	166	4.8	5	4.4
1053	PL-4008	OAPLPOM20	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5.2	166	4.8	5	4.4
1054	PL-4009	OAPLPOM10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5	87	5	5.2	4.6
1055	PL-4009	OAPLPOM21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5	87	5	5.2	4.6
1056	PL-4010	OAPLPOM08	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5.4	208	4.9	5.1	4.5

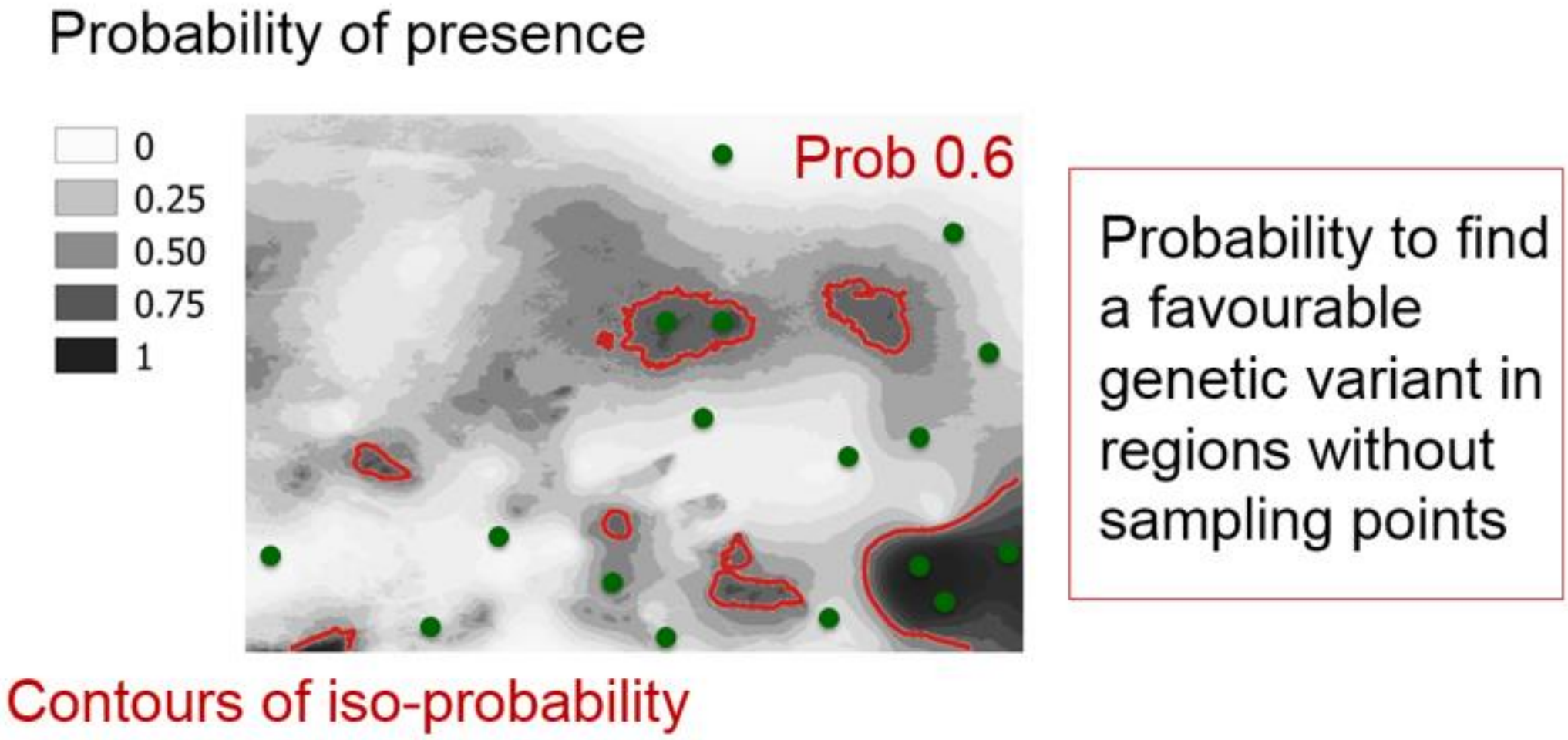
- Multiple parallel logistic regressions (Joost et al. 2007): MatSAM, Sambada, R. Sambada software developed in our lab (Joost et al. 2008; Stucki et al. 2017, Duruz et al. 2019)
- Billions of association models calculated (millions of genomic loci x hundreds of environmental variables)

Genes under natural selection



Many different genomic regions (SNPs = Single Nucleotide Polymorphisms) associated with different environmental variables (colors). The red line shows the significance level.

Predict where favorable genetic variants are required



SPAG : Spatial Areas of Genotype Probability

SPAGs for Moroccan sheep breeds

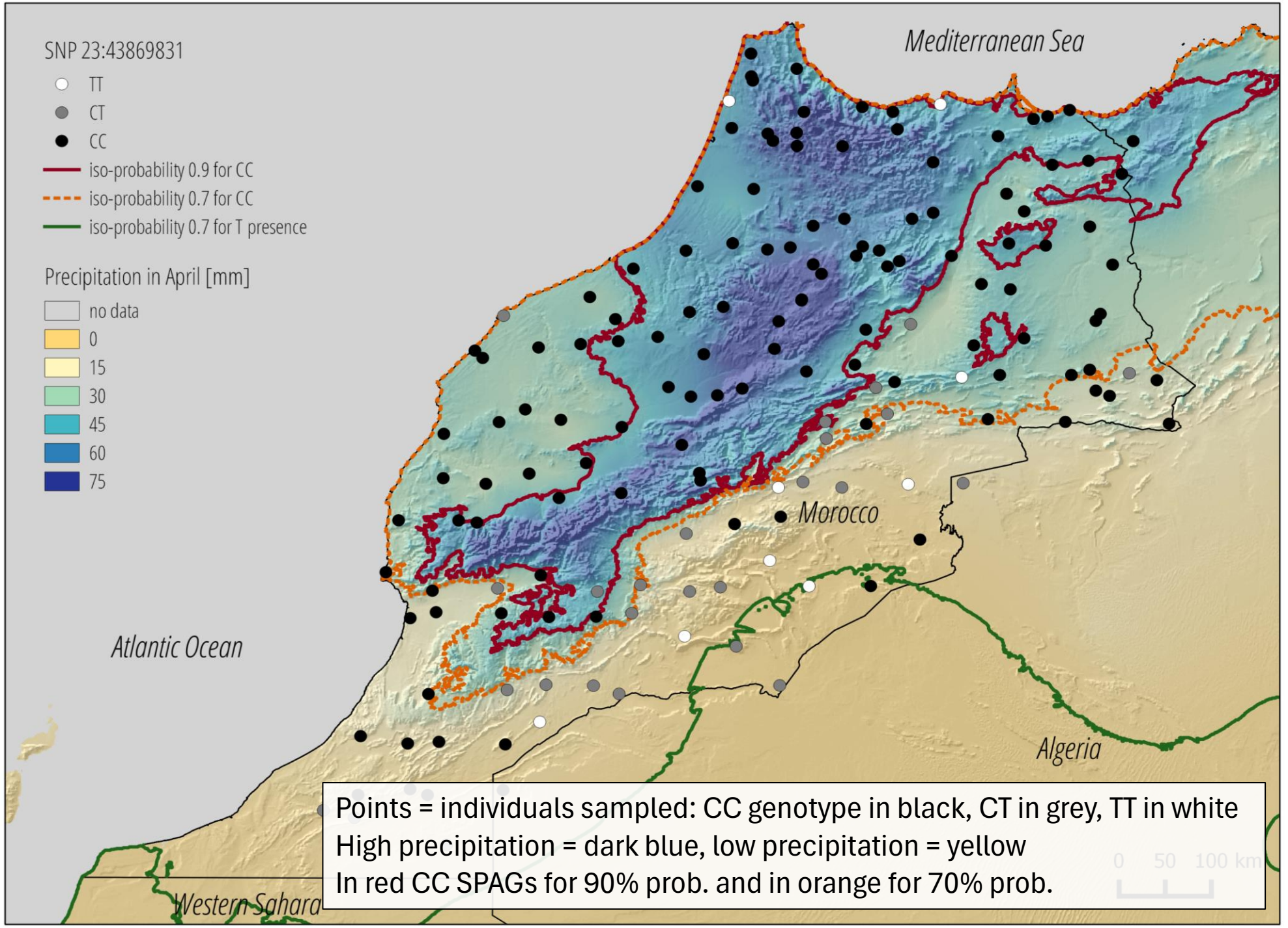
- Whole genome sequence (WGS) - 38.5 M SNPs (nextgen.epfl.ch)
- Detection of a specific SNP on **gene MC5R** significantly associated with precipitation
- SPAGs to delimit the geographic regions where this genotype is currently present
- Worldclim 2070 predictions for severe climate change (scenario GISS-E2-R, rcp 85), http://www.worldclim.com/)
- Map the predicted SPAG shift in the future

MC5R

- MC5R codes for a protein most likely involved in lanolin (wax) production (Chen et al. 1997)
- The CC genotype (without allele T) is positively correlated with precipitation
- Another genotype with allele T shows a negative association with precipitation

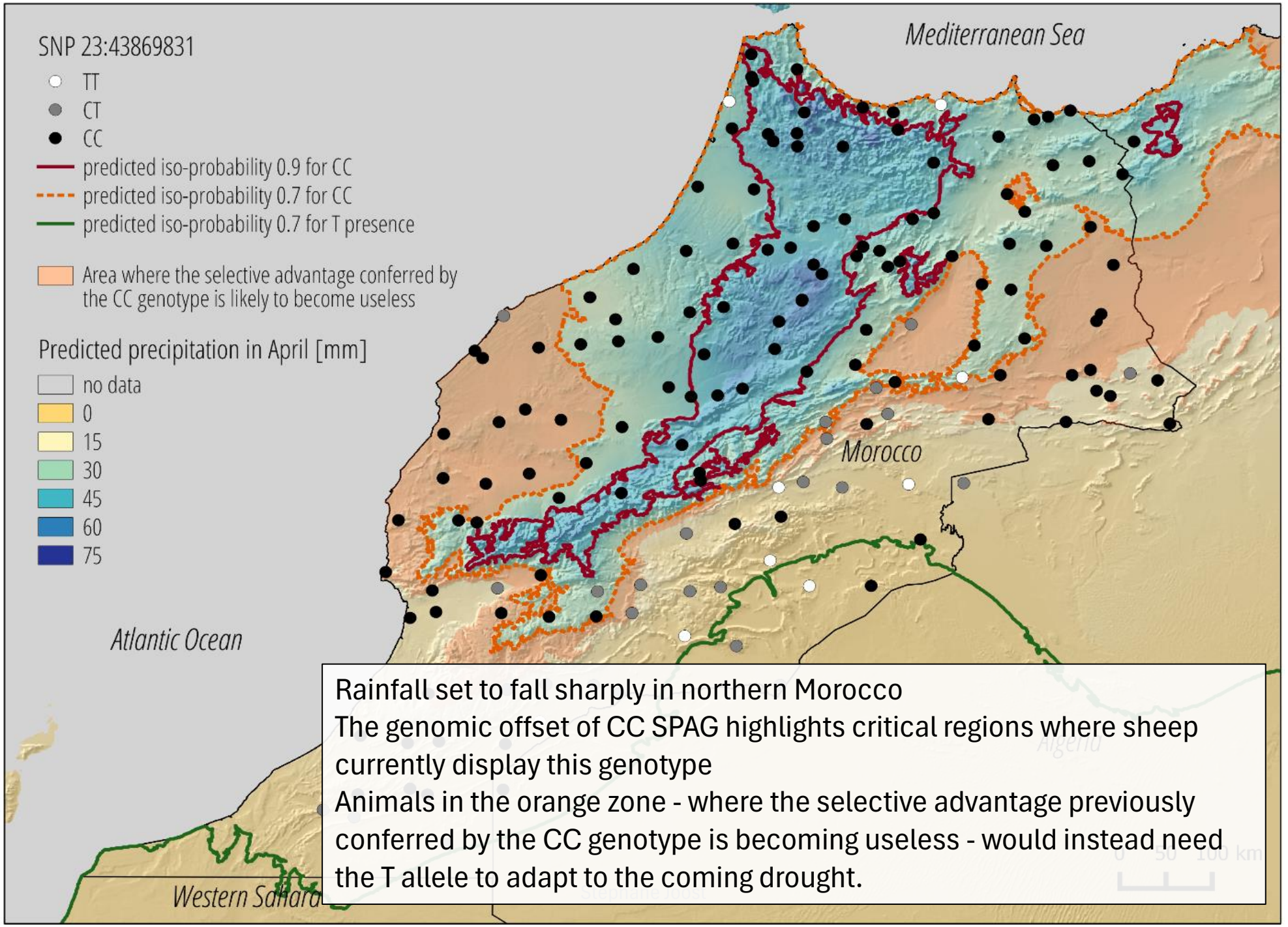
- CC could favor the production of lanolin and prevent the lumpy wool disease in sheep
- While allele T is likely to reduce this production and favor adaptation to drought

2020



Points = individuals sampled: CC genotype in black, CT in grey, TT in white
High precipitation = dark blue, low precipitation = yellow
In red CC SPAGs for 90% prob. and in orange for 70% prob.

2070

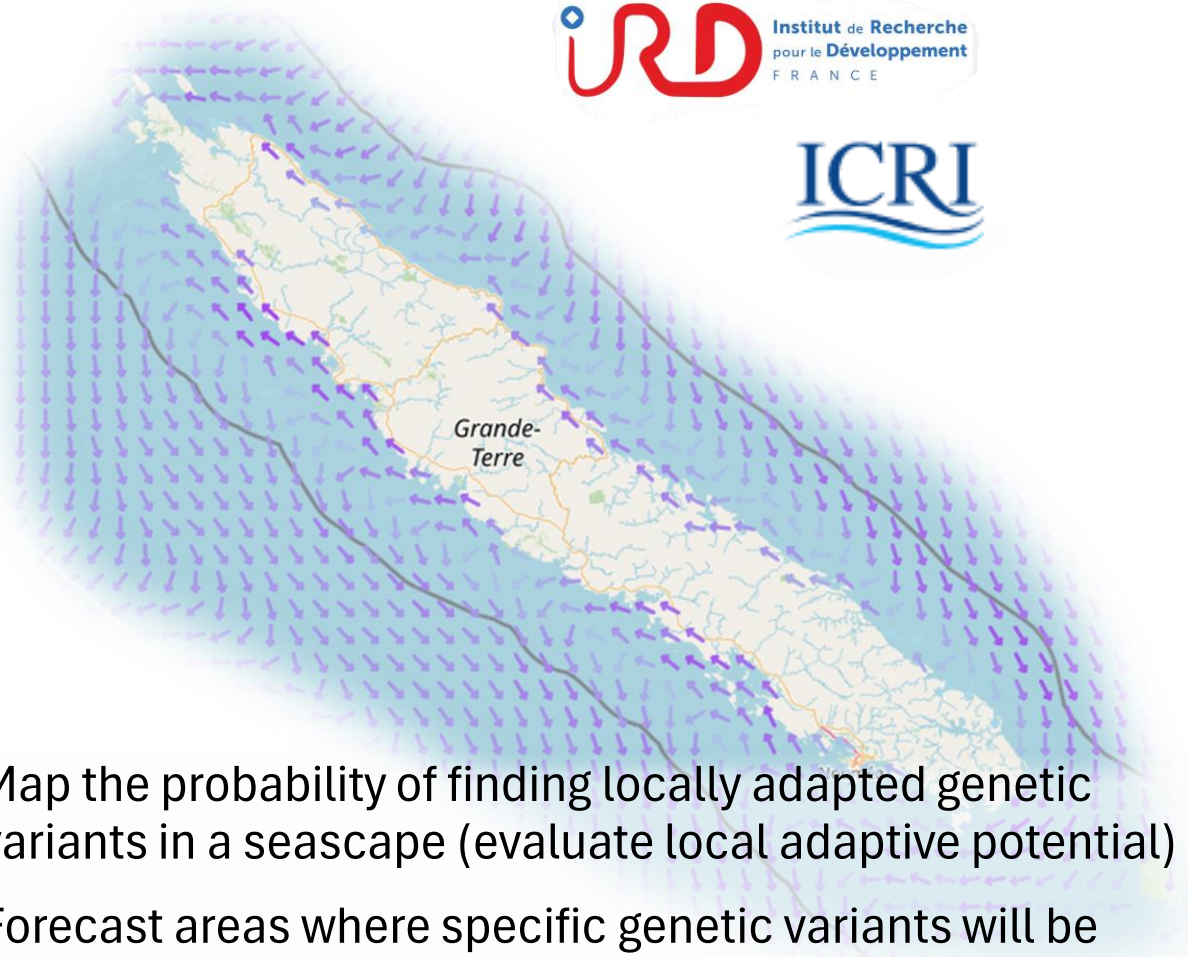


Rainfall set to fall sharply in northern Morocco
The genomic offset of CC SPAG highlights critical regions where sheep currently display this genotype
Animals in the orange zone - where the selective advantage previously conferred by the CC genotype is becoming useless - would instead need the T allele to adapt to the coming drought.

Use of adaptive potential in conservation

- Information on adaptive potential is key to predict the response of species to climate change
- Main application of adaptive potential is prioritization of areas based on the information characterizing evolutionary processes
- Use of SPAGs can help identify:
  - Well-adapted populations with adaptive genotypes expected to be optimal under future conditions
  - Threatened populations, with “missing” genetic variants, unable to adapt, like e.g. coral reef species under heat stress (bleaching)

Seascape genomics for the conservation of coral reefs



- Map the probability of finding locally adapted genetic variants in a seascape (evaluate local adaptive potential)
- Forecast areas where specific genetic variants will be necessary in the future according to environmental changes
- Locate Marine Protected Areas (MPAs) or coral nurseries

Selmoni et al. 2021

ENV-167

Introduction to environmental engineering

The role of geographic information in spatial epidemiology

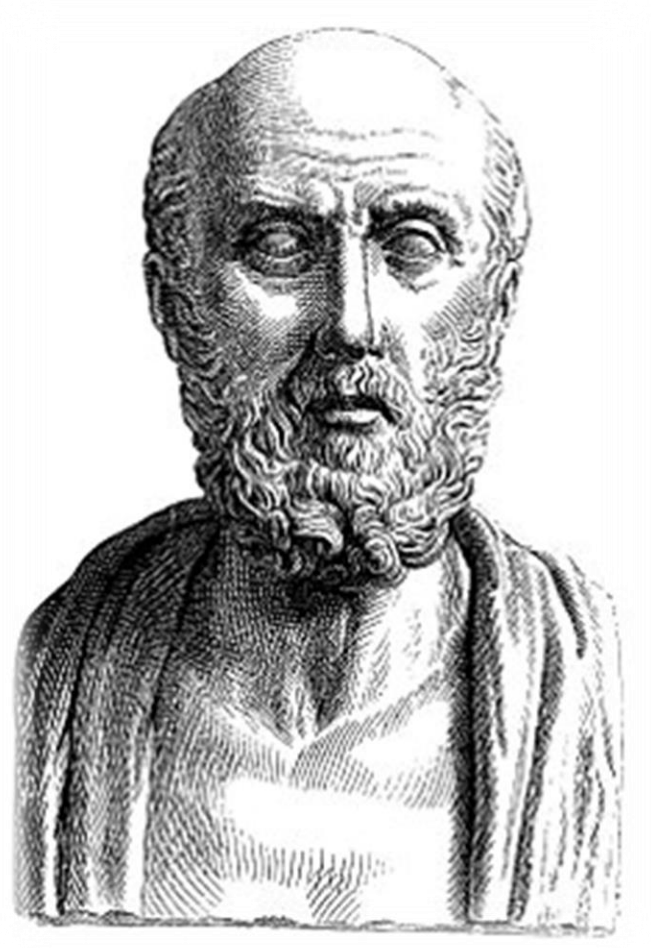
Stéphane Joost

Group of Geospatial Molecular Epidemiology (GEOME)

Laboratory for Biological Geochemistry (LGB)

Health and place

- The study of the relationship between health and place: Hippocrates
- "Airs, waters, and places" influences a whole section of medicine (more than 2,000 years ago)
- Air and water quality must be considered, but also the socio-economic environment and behaviors
- Medical geography: largely based on associations between health and place

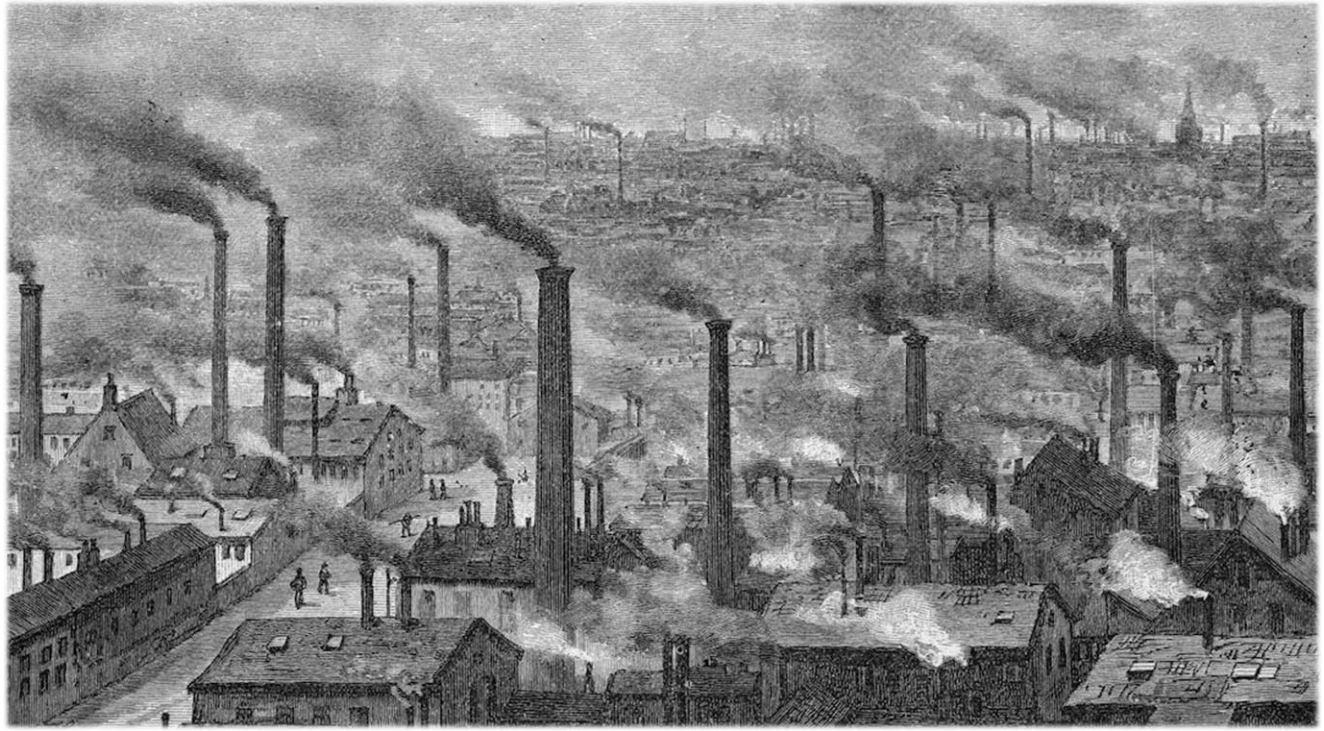


Disease and lockdown areas

- Plague
- 1690 – 1692 in the province of Bari (Filippo Arrieta)
- The map shows areas most affected by plague
- It highlights boundaries of a quarantine zone imposed to prevent its spread to neighboring towns and other provinces

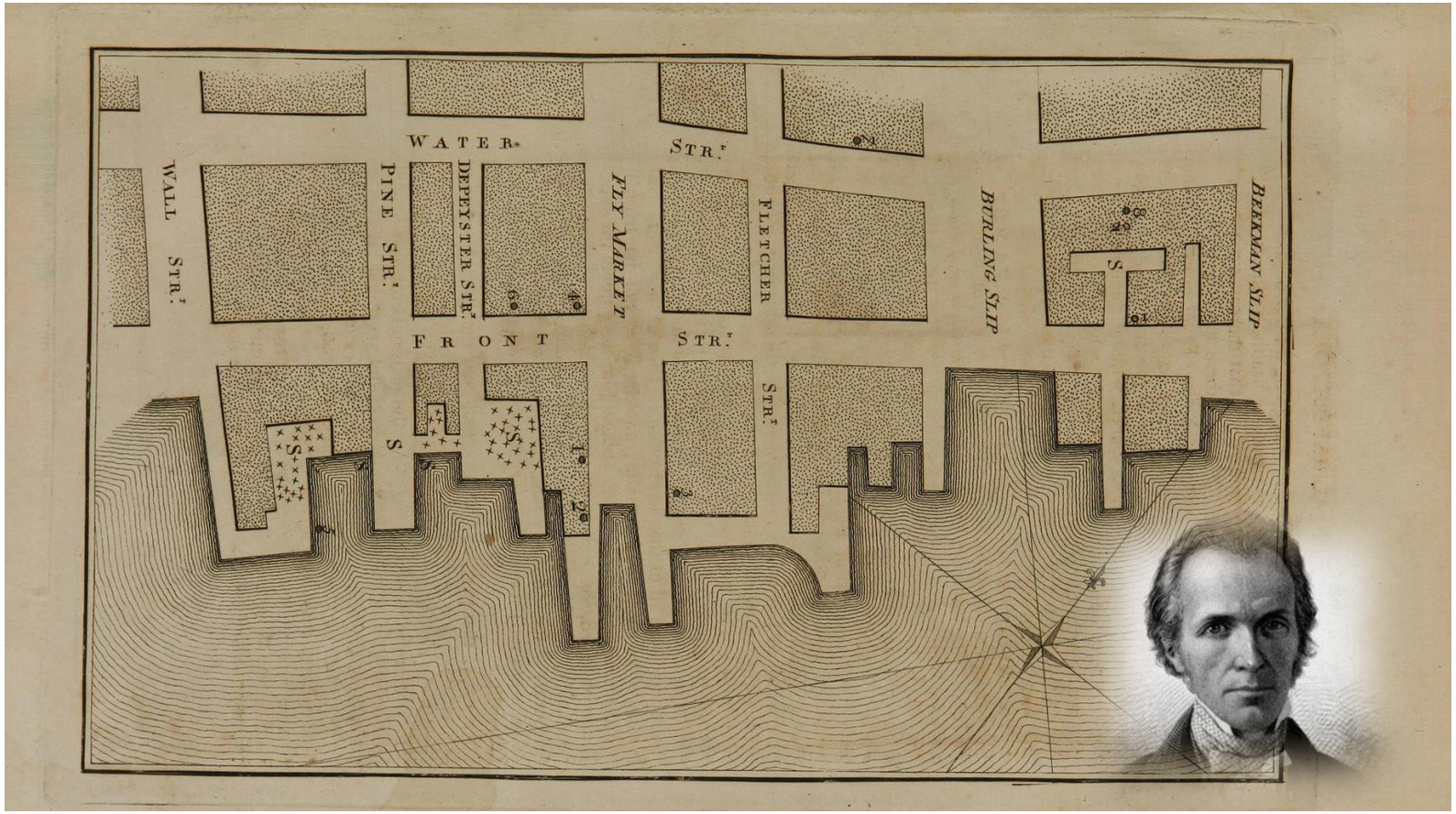
Industrial revolution

- Industrial revolution end of 18th Century: many public health issues
- Need to inform about risk areas where tuberculosis, cholera or yellow fever appear most frequently
- Emergence of medical cartography

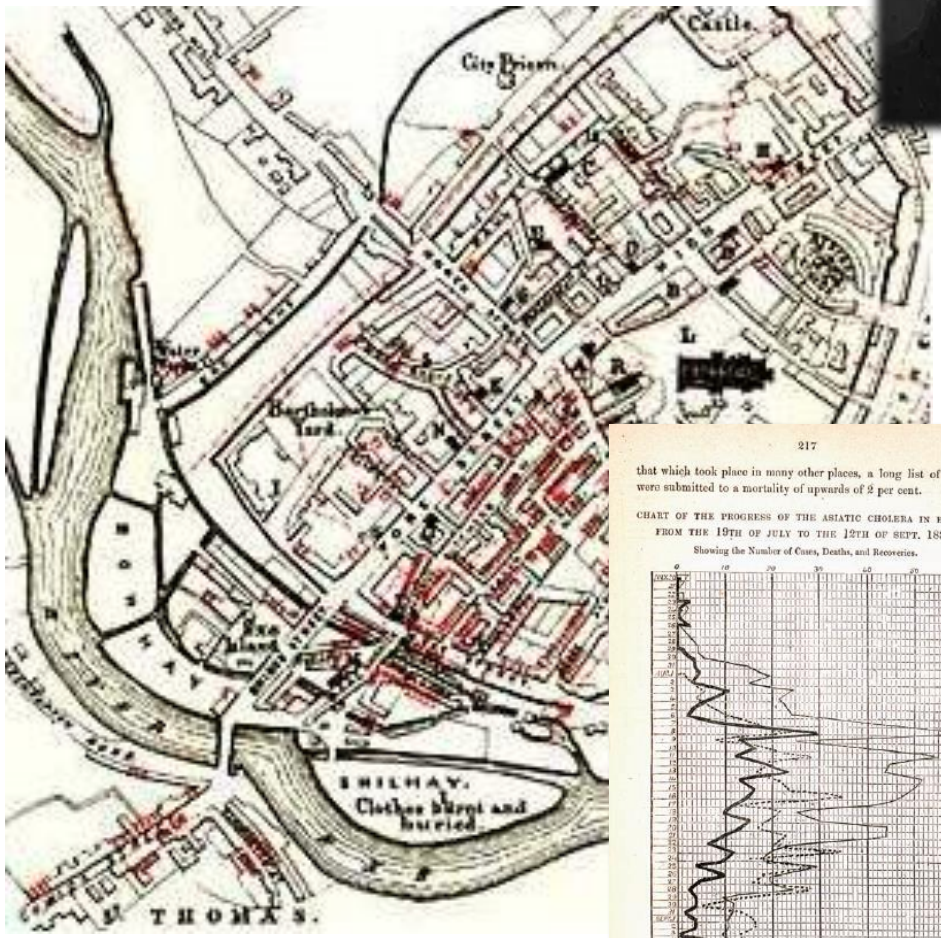


Yellow fever

- 1798 - Valentine Seaman, a surgeon at New York Hospital, investigated the yellow fever outbreak in his city
- Seaman argued the origin of the city's disease outbreak was the smell that arose from the garbage and sewage that accumulated in the harbor area
- "In the city there appears to be an intimate and inseparable connection between the prevalence of yellow fever and the existence of putrid effluvia"



Cholera



217

that which took place in many other places, a long list of which were submitted to a mortality of upwards of 2 per cent.

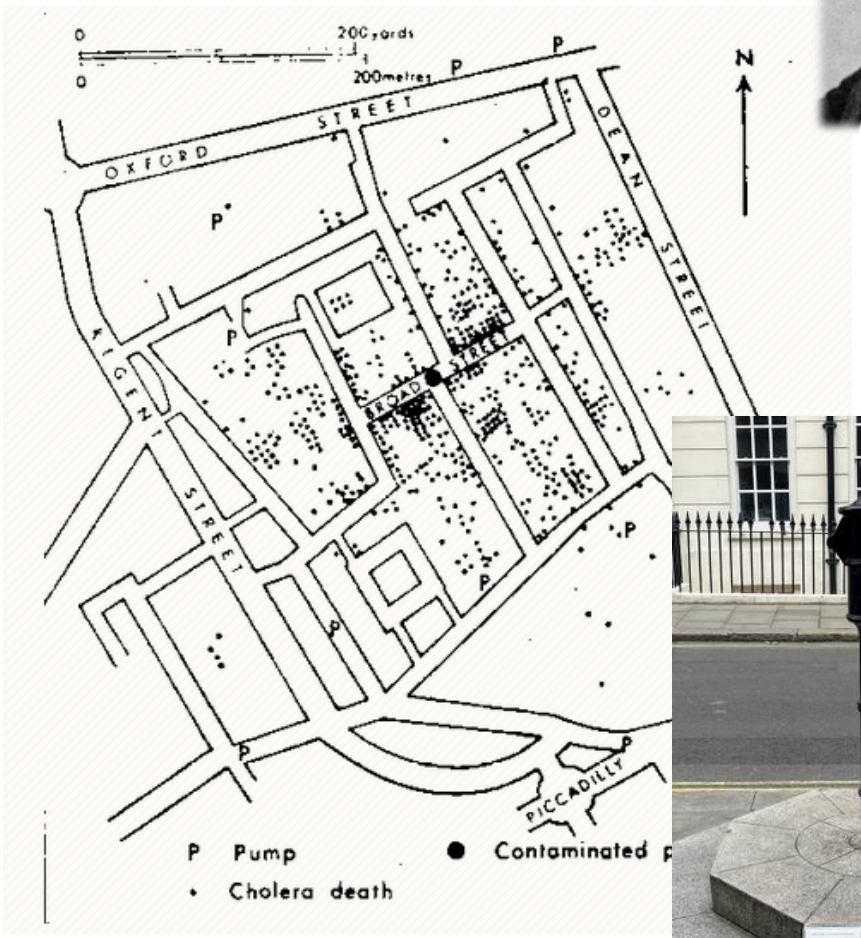
CHART OF THE PROGRESS OF THE ASIATIC CHOLERA IN EXETER FROM THE 19TH OF JULY TO THE 12TH OF SEPT. 1832;

Showing the Number of Cases, Deaths, and Recoveries.

New Cases—— Deaths —— Recoveries.....

It has been a not unfrequent statement, and I believe is an opinion commonly entertained, that during the progress of plagues

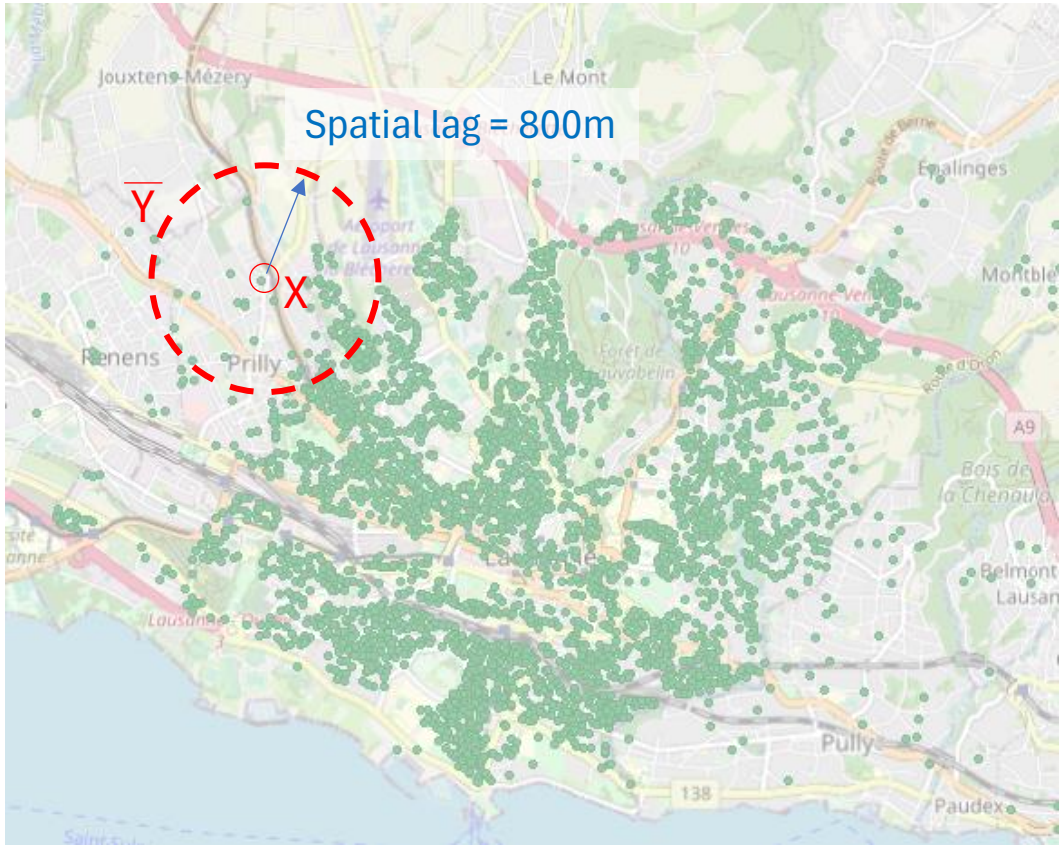
Thomas Schapter
Exeter 1832



John Snow
London, 1854

Medical cohorts

- Participants in medical cohorts precisely located in space
- Method: georeferencing
- X,Y (geographic coordinates) of places of residence (Rue Neuve 14, 1009 Pully)
- **First law of geography** "Everything is related to everything else, but near things are more related than distant things" (Tobler, 1970)
- Measuring spatial dependence

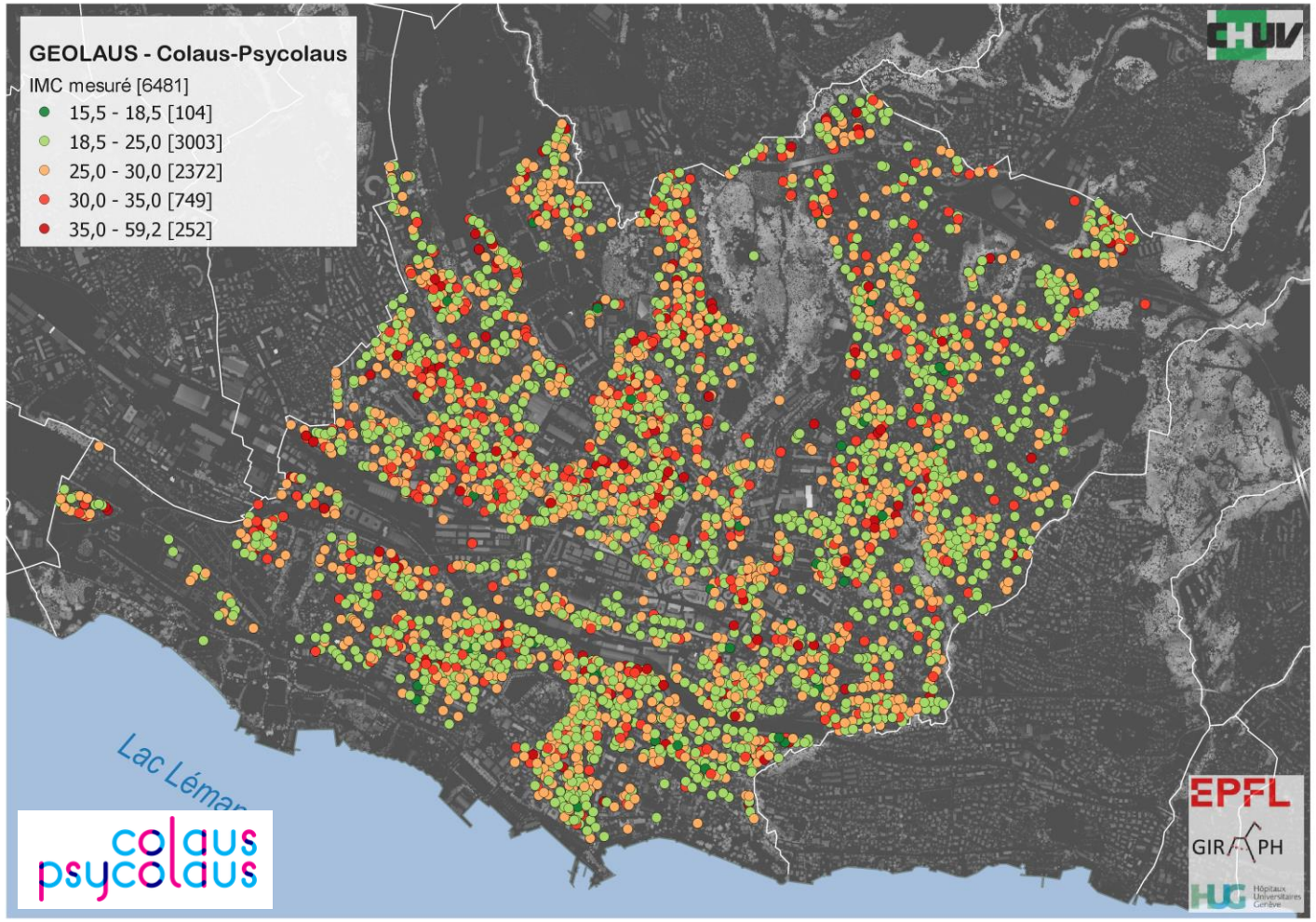


Does X look like $\overline{Y}$?

Without Tobler's law

- No detectable signal through standard thematic mapping

Classification en fonction de l'indice de masse corporelle	
Insuffisance pondérale	< 18.5
Éventail normal	18.5 - 24.9
Surpoids	⩾ 25.0
Préobésité	25.0 - 29.9
Obésité	⩾ 30.0
Obésité, classe I	30.0 - 34.9
Obésité, classe II	35.0 - 39.9
Obésité, classe III	⩾ 40.0



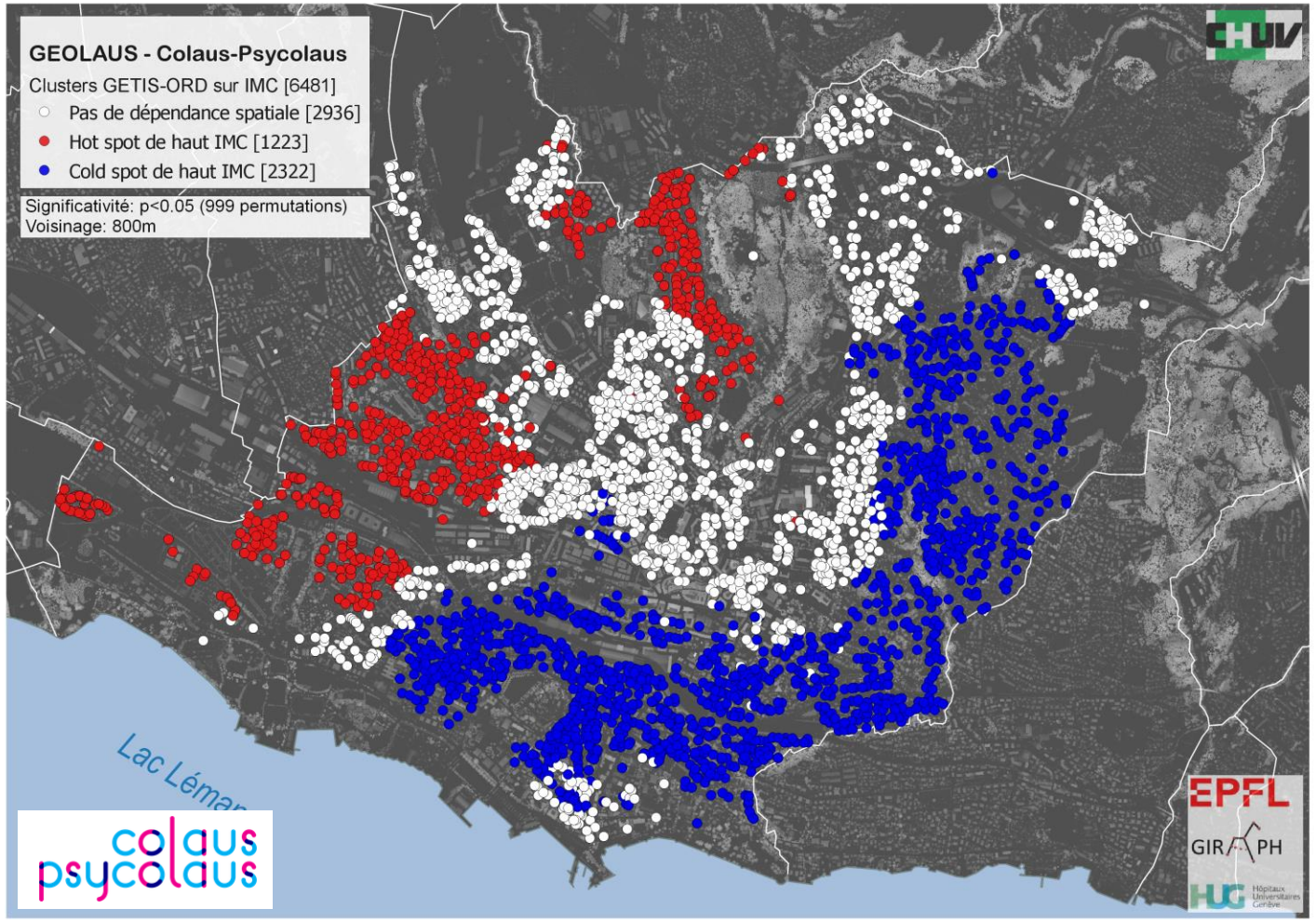
Body Mass Index, Colaus-PsyColaus cohort

Joost et al. 2016

With Tobler's law

Spatial dependence, spatial statistics

- Specific statistical tools
- Key to make the invisible visible!
- Potential to develop **targeted prevention actions** where needed!

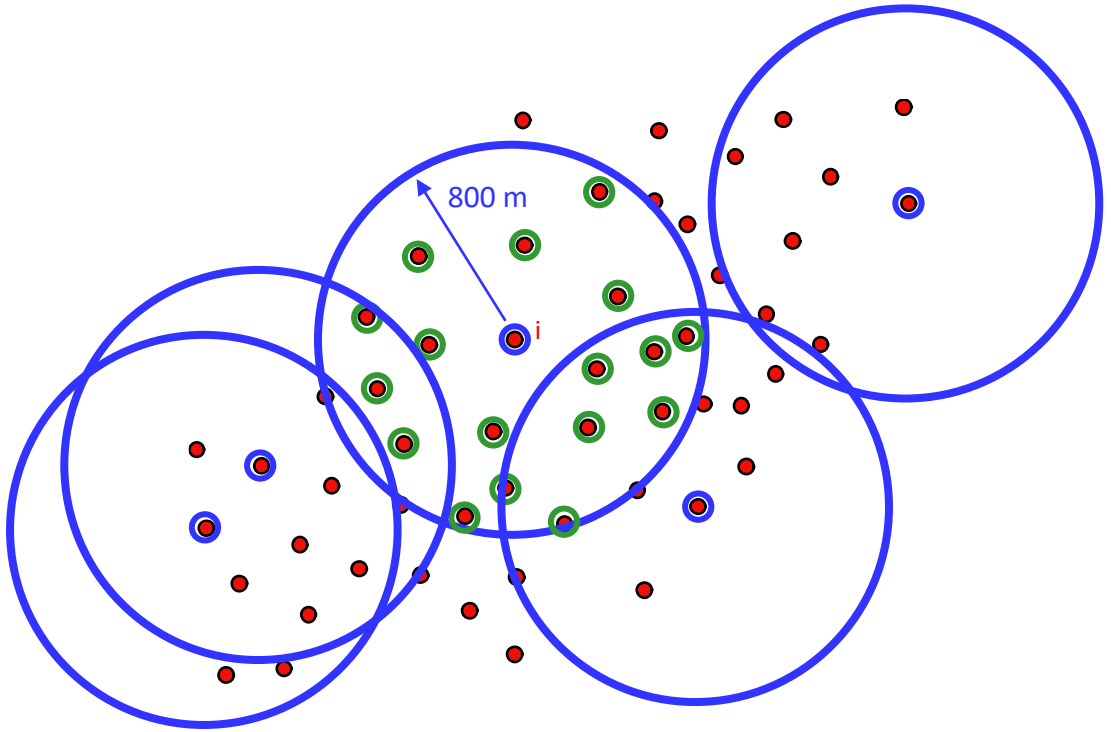


Body Mass Index, Colaus-PsyColaus cohort

Joost et al. 2016

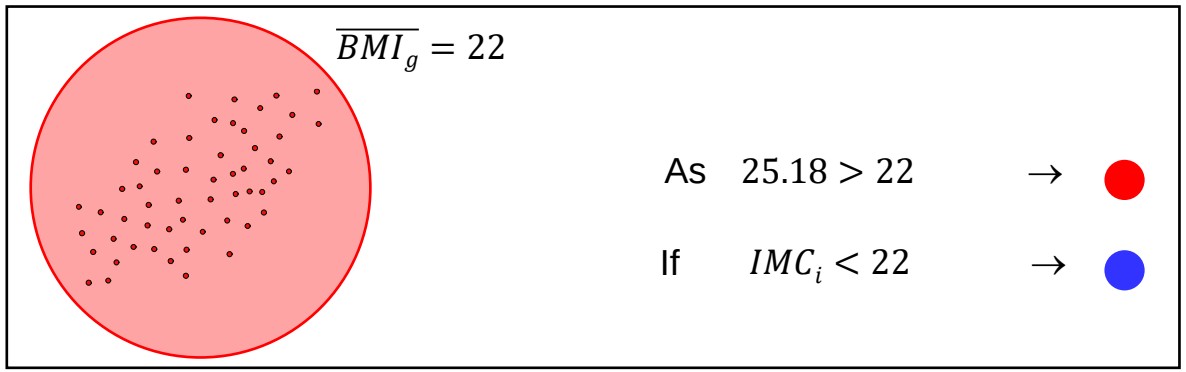
How to measure spatial dependence ?

- Use neighborhood relationships
- "How much" an individual resembles his neighbors in a given neighborhood
- Example with body mass index (BMI) and Getis-Ord statistics
- BMI = $\frac{Weight}{(Height)^2}$



BMI=23
BMI=21
BMI =27
BMI =23
BMI =29
BMI =23
BMI =33
BMI =35
BMI =18
BMI =23
BMI =22
BMI =26
BMI =27
BMI =27
BMI =25
BMI =21

$\overline{BMI_i} = 25.18$



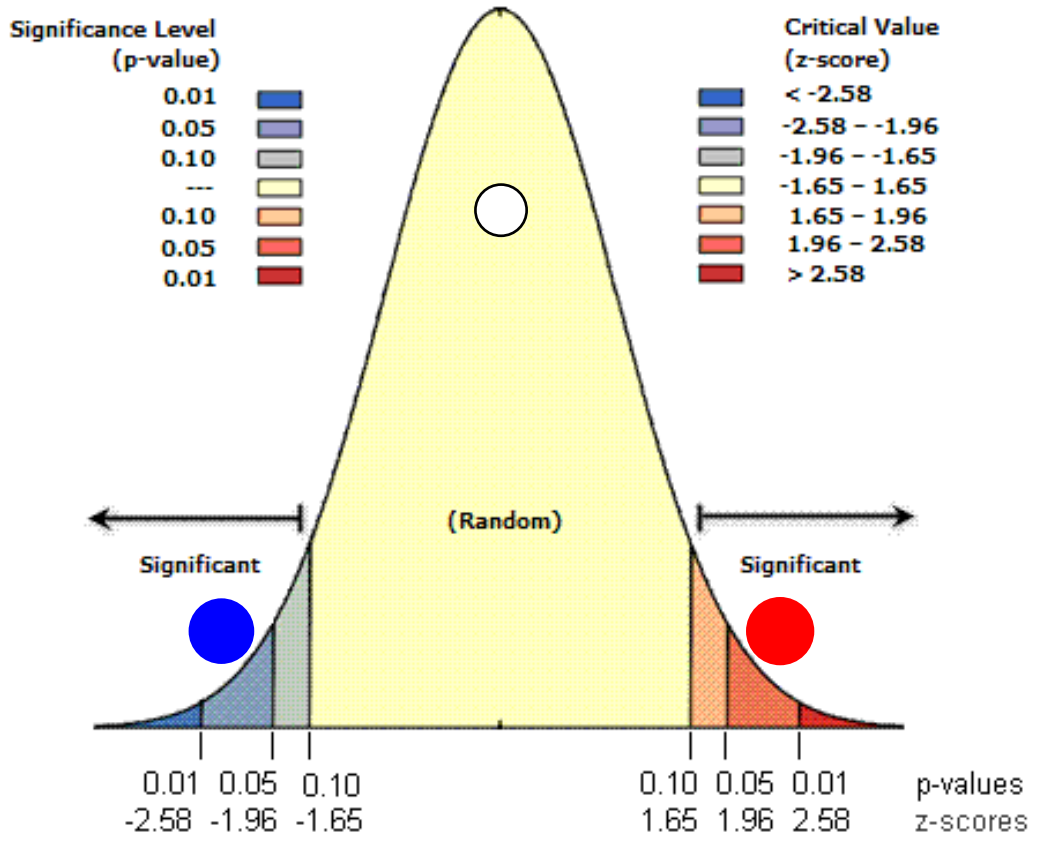
Spatial dependence or random distribution?

- Null hypothesis: the observed local value is not different from the general mean
- Random permutations on standardized BMI
- T-test* to compare the means

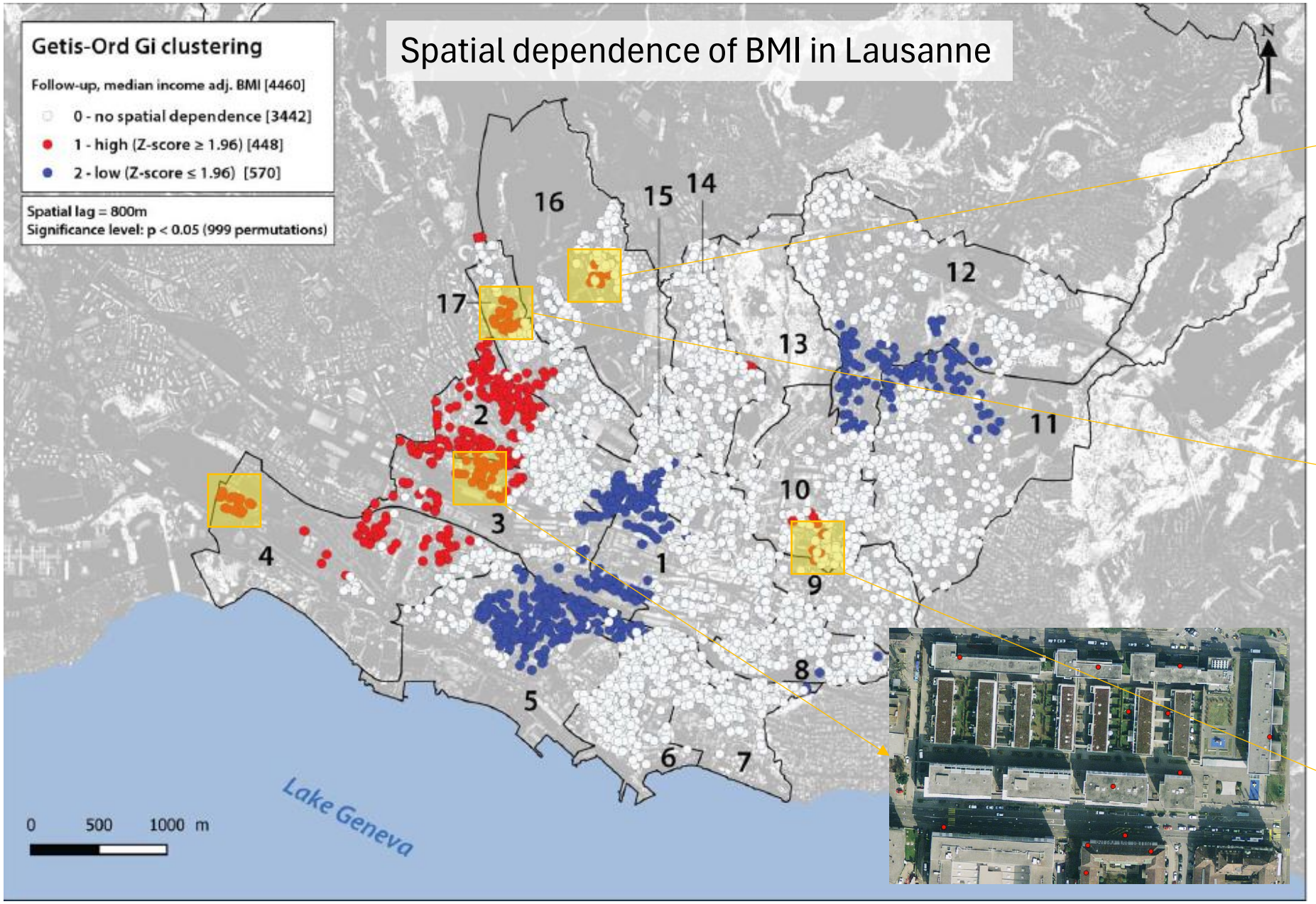
Significantly lower than the general average, the value depends on its geographical location

Random value, does not depend on its geographical location

Significantly higher than the general average, the value depends on its geographical location



Spatial dependence of BMI in Lausanne

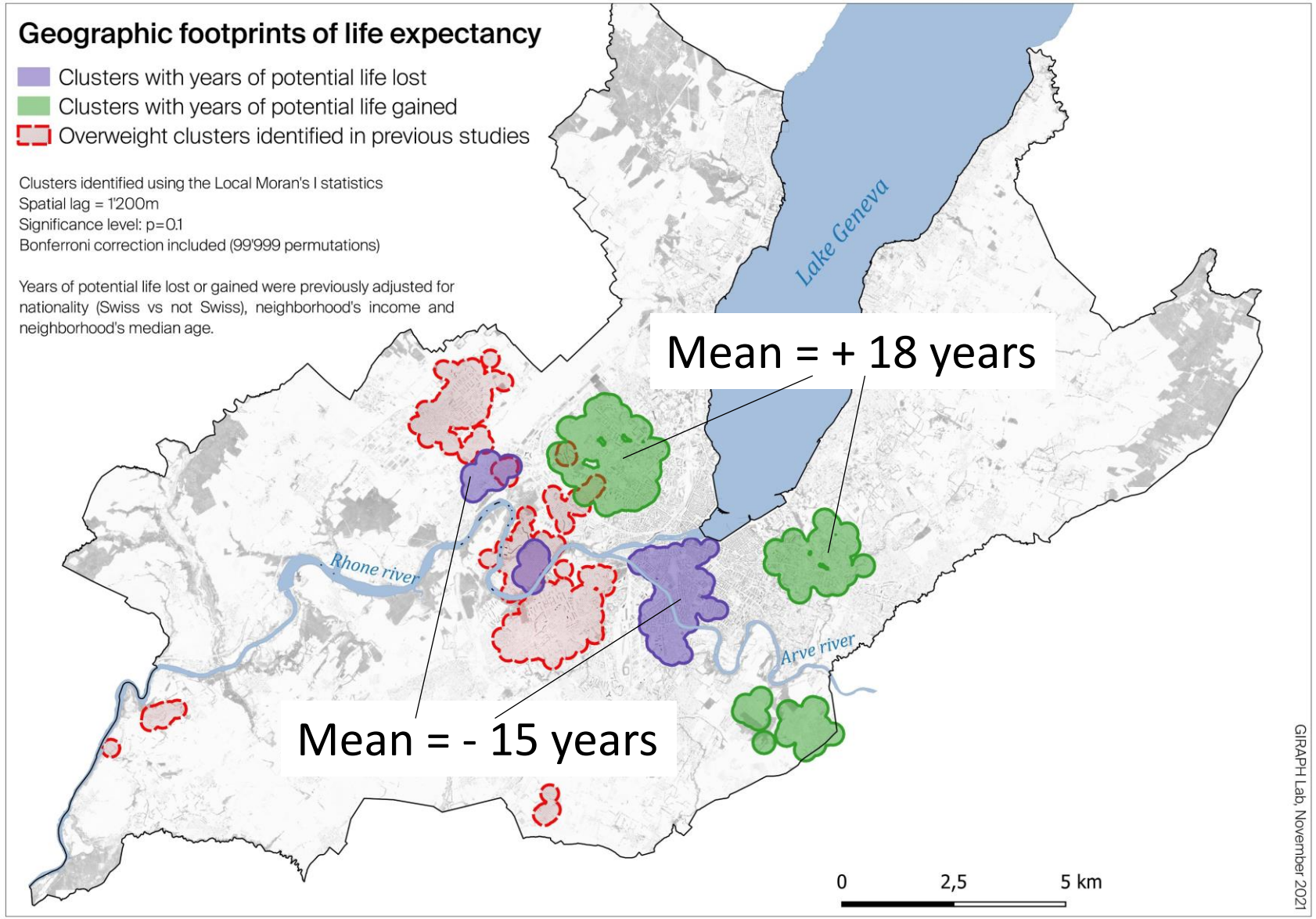


Joost et al. 2016

Geographical containment

Difference in life expectancy at birth

- Green zones gain an average of 18 years on life expectancy at birth
- Purple areas lose an average of 15 years compared with life expectancy at birth
- These are areas where unfavorable conditions such as soil and air pollution have accumulated over the years (Jonction and west of the Arve river)



Ladoy et al. 2021

Characterising clusters with environmental variables

- Natural and built environment (pollution, vegetation, etc.)
- Socio-economic environment
- Demographic environment
- Cultural environment (language, religion, etc.)

"The Swiss Confederation estimates the health costs of traffic noise at CHF 2.6 billion. It increases risks in several areas: cardiovascular, psychological, and sleep. In 2018, a study carried out in Lausanne demonstrated the link between noisy neighborhoods and heavy daytime sleepiness, and hence lack of sleep."

Publié le 29 avril 2019

Road traffic noise in Lausanne

24heures SIGNÉ LAUSANNE

Vaud & Régions Suisse Monde Économie Sports Savoirs Culture High-Tech People Vivre Auto Plus

Lausanne & Région Riviera-Chablais Nord vaudois-Broye La Côte Faits divers Signé Lausanne
L'actu en dessins Images Clic-clac

Le PS lausannois lance l'idée d'un centre-ville à 30 km/h

Bruit La conseillère Anne-Françoise Decollogny suggère la mesure pour lutter contre le bruit routier excessif.

Anne-Françoise Decollogny se félicite des tests nocturnes menés à Vinet-Beaulieu et propose désormais d'aller plus loin.

Image: Florian Cella

Un logiciel pour prédire le bruit qu'il fera

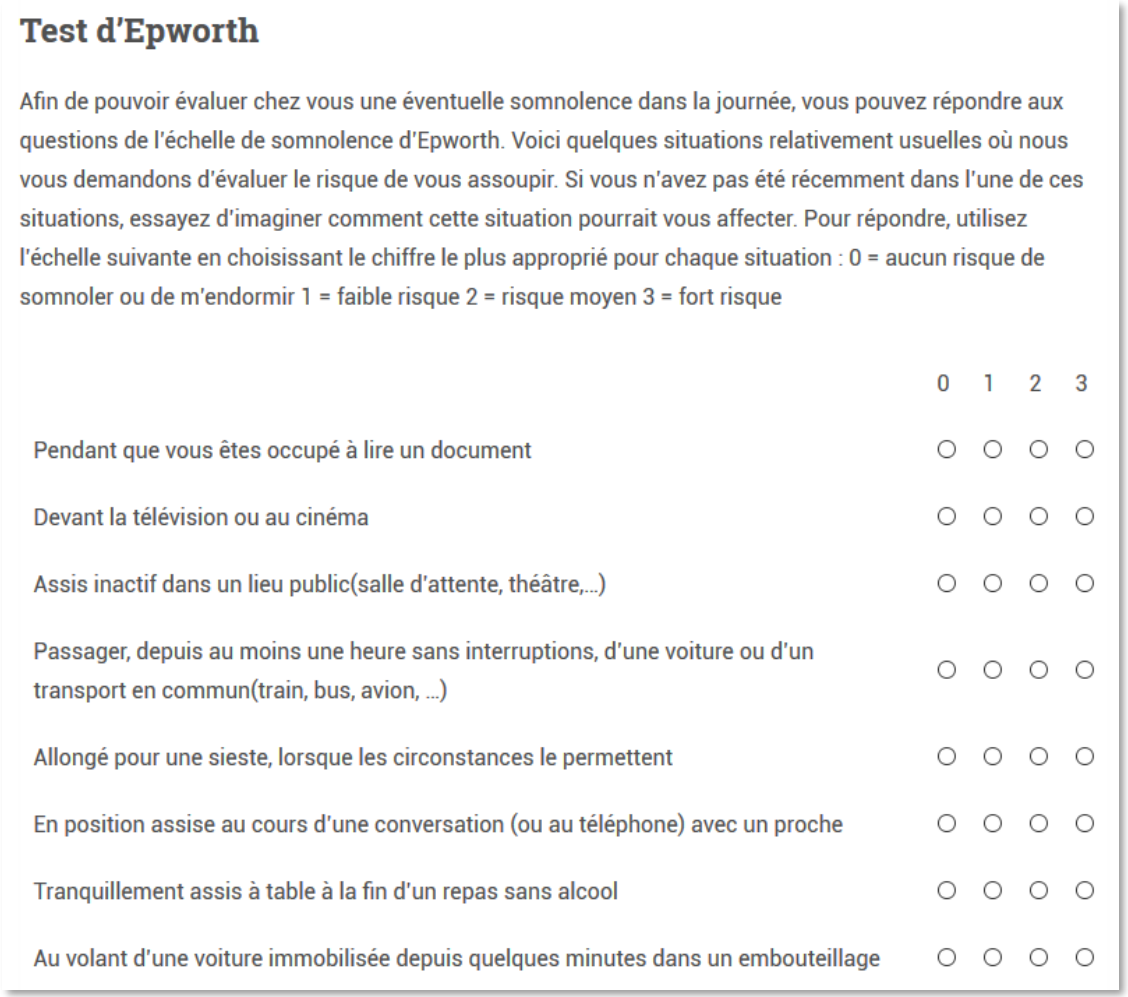
Dans le cadre de la lutte contre le bruit à Lausanne, la Municipalité veut acheter un logiciel (CadnaA) spécialisé dans sa prédiction. En simple: un outil informatique pour prévoir le bruit qu'il va faire. Il est présenté par ses concepteurs comme la solution «la plus performante» pour le calcul, l'évaluation, la prévision et la représentation de l'impact du bruit dans l'environnement. Son coût, qui figure dans la première série de crédits supplémentaires pour le budget 2018 de la Ville de Lausanne: 12'000 francs.

Spatial clusters of daytime sleepiness in Lausanne

- Colaus-PsyColaus study, a longitudinal study in the population of Lausanne
- 6700 participants recruited between 2001 and 2003 (baseline)
- 2009-2012: follow-up study
- Hypnolaus substudy: 3700 subjects from the baseline sample, georeferenced at their place of residence
- Questionnaires on daytime sleepiness
- Sleepiness measured using the **Epworth Sleepiness Scale** (ESS)

Epworth Sleepiness Scale (ESS)

- The 3700 participants in the GeoHypnolaus study completed a short questionnaire to quantify daytime sleepiness
- The Epworth Sleepiness Scale estimates the probability of falling asleep in everyday situations
- The higher the score, the greater the daytime sleepiness, and the more likely it is that the person is experiencing night-time sleep problems, including sleep disturbed by environmental factors

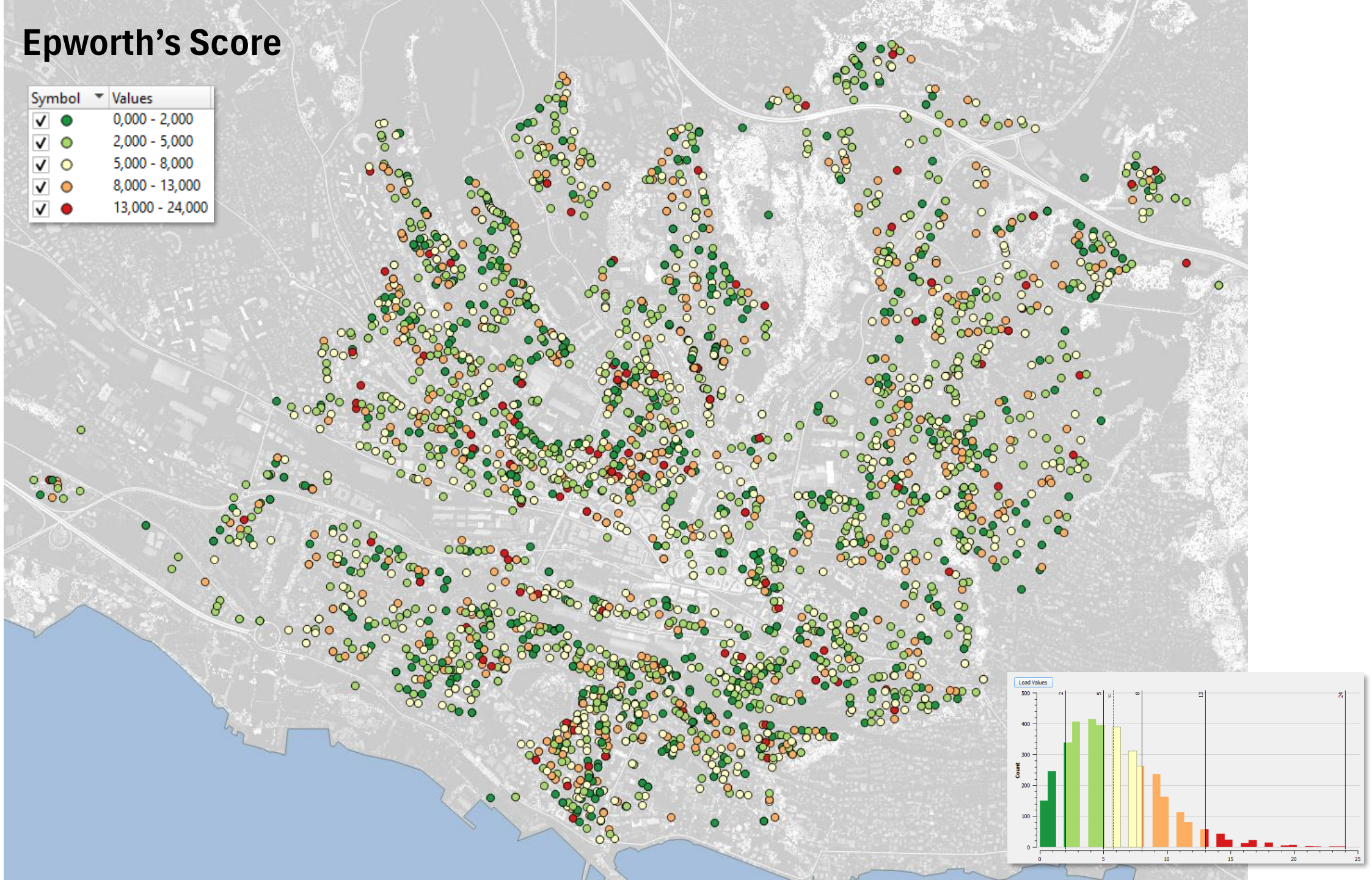


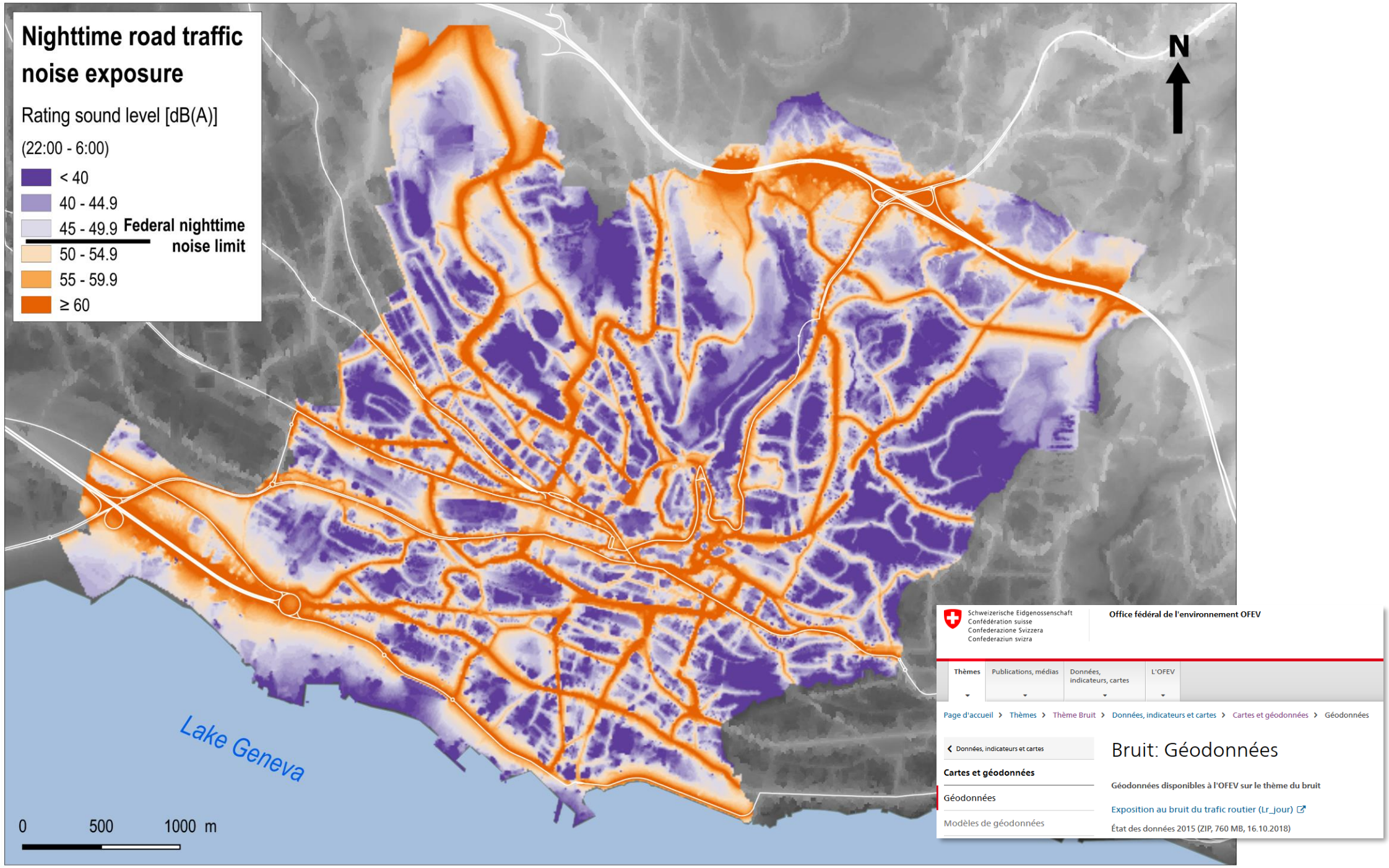
Test d'Epworth

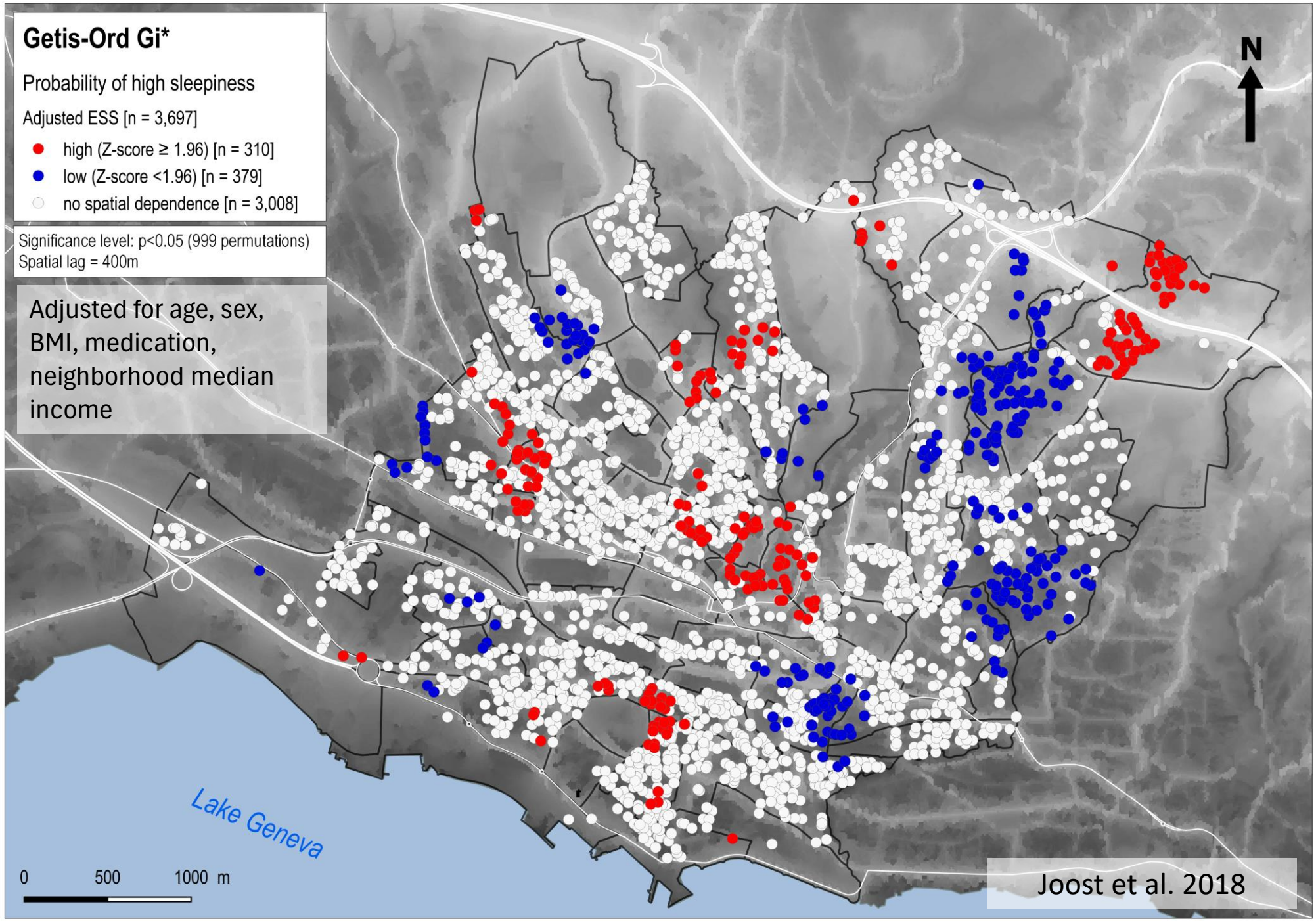
Afin de pouvoir évaluer chez vous une éventuelle somnolence dans la journée, vous pouvez répondre aux questions de l'échelle de somnolence d'Epworth. Voici quelques situations relativement usuelles où nous vous demandons d'évaluer le risque de vous assoupir. Si vous n'avez pas été récemment dans l'une de ces situations, essayez d'imaginer comment cette situation pourrait vous affecter. Pour répondre, utilisez l'échelle suivante en choisissant le chiffre le plus approprié pour chaque situation : 0 = aucun risque de somnoler ou de m'endormir 1 = faible risque 2 = risque moyen 3 = fort risque

	0	1	2	3
Pendant que vous êtes occupé à lire un document	○	○	○	○
Devant la télévision ou au cinéma	○	○	○	○
Assis inactif dans un lieu public(salle d'attente, théâtre,...)	○	○	○	○
Passager, depuis au moins une heure sans interruptions, d'une voiture ou d'un transport en commun(train, bus, avion, ...)	○	○	○	○
Allongé pour une sieste, lorsque les circonstances le permettent	○	○	○	○
En position assise au cours d'une conversation (ou au téléphone) avec un proche	○	○	○	○
Tranquillement assis à table à la fin d'un repas sans alcool	○	○	○	○
Au volant d'une voiture immobilisée depuis quelques minutes dans un embouteillage	○	○	○	○

Epworth's Score

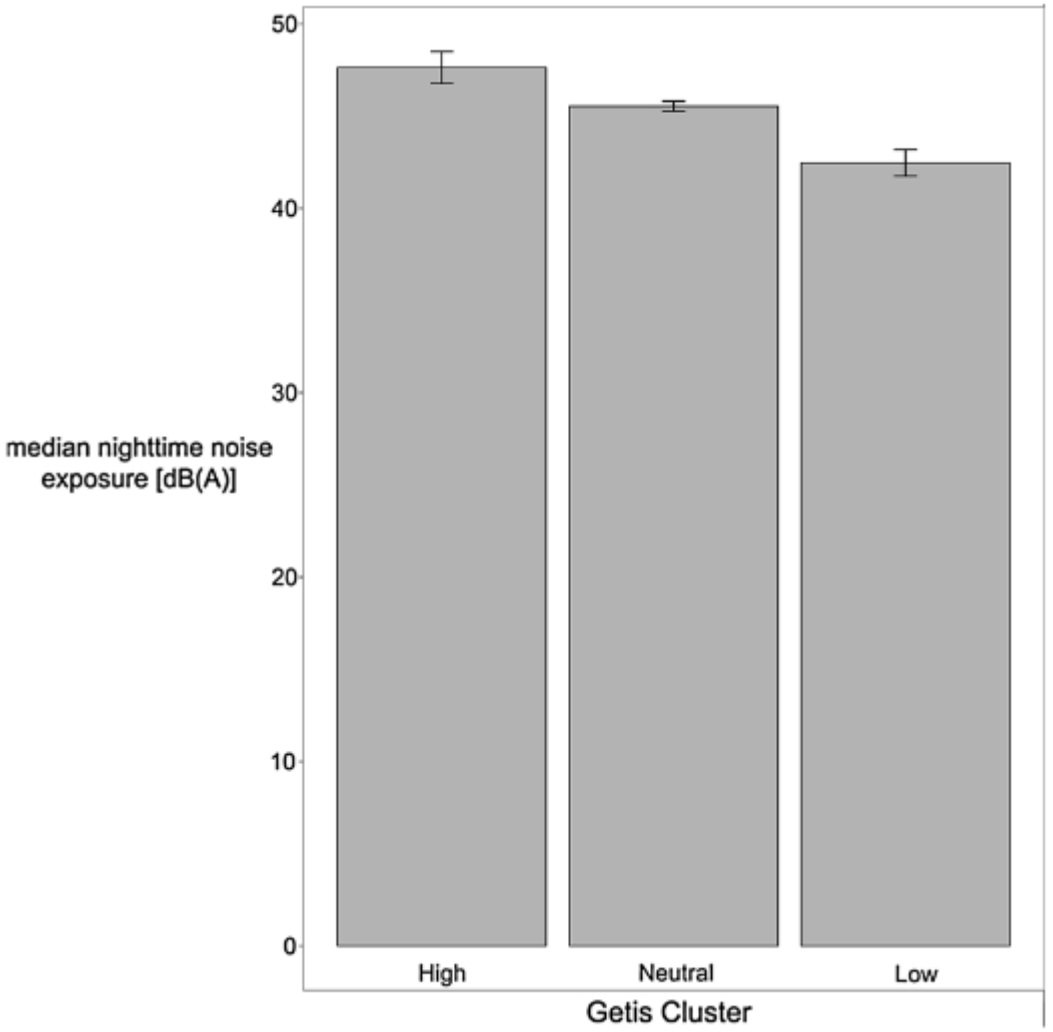



Nighttime road traffic noise exposure
Rating sound level [dB(A)]
(22:00 - 6:00)
< 40
40 - 44.9
45 - 49.9
Federal nighttime noise limit
50 - 54.9
55 - 59.9
≥ 60
N
Lake Geneva
0
500
1000 m
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Office fédéral de l'environnement OFEV
Thèmes
Publications, médias
Données, indicateurs, cartes
L'OFEV
Page d'accueil › Thèmes › Thème Bruit › Données, indicateurs et cartes › Cartes et géodonnées › Géodonnées
Données, indicateurs et cartes
Cartes et géodonnées
Géodonnées
Modèles de géodonnées
Bruit: Géodonnées
Géodonnées disponibles à l'OFEV sur le thème du bruit
Exposition au bruit du trafic routier (Lr_jour)
État des données 2015 (ZIP, 760 MB, 16.10.2018)


Getis-Ord Gi*
Probability of high sleepiness
Adjusted ESS [n = 3,697]
high (Z-score ≥ 1.96) [n = 310]
low (Z-score <1.96) [n = 379]
no spatial dependence [n = 3,008]
Significance level: p<0.05 (999 permutations)
Spatial lag = 400m
Adjusted for age, sex, BMI, medication, neighborhood median income
N
Lake Geneva
0
500
1000 m
Joost et al. 2018

Results

- Variance analysis on cluster classes (Tukey's HSD)
- We observe a dose-response effect
- Getis-Ord: median nighttime noise in the high clusters was 2.10 dB(A) higher than in the neutral class ($p < 0.001$) and **5.16 dB(A) higher than in low clusters** ($p < 0.001$)
- Local Moran's I classes show a dose-response effect too
- The difference between the nighttime noise levels in the high-high and low-low clusters was **4.49 dB(A)** ($p < 0.001$)



Use of results by the city of lausanne

International Journal of Hygiene and Environmental Health 221 (2018) 951–957

Contents lists available at ScienceDirect

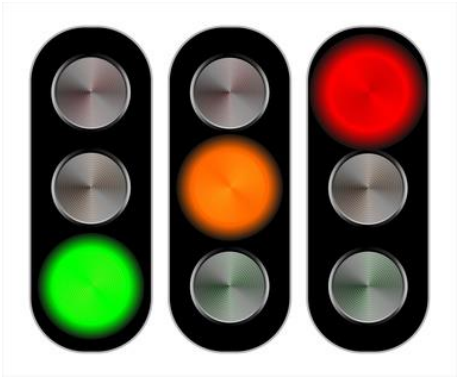
International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

Spatial clusters of daytime sleepiness and association with nighttime noise levels in a Swiss general population (GeoHypnoLaus)

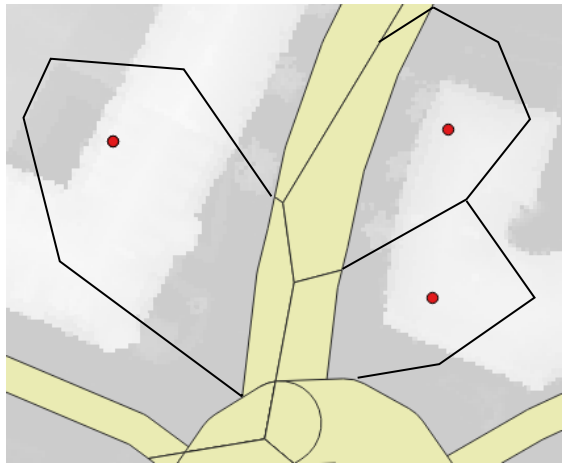
Stéphane Joost[a,b,c,1], José Haba-Rubio[d,1], Rebecca Himsl[a,b,c], Peter Vollenweider[e], Martin Preisig[g], Gérard Waeber[e], Pedro Marques-Vidal[c,e], Raphaël Heinzer[d,2], Idris Guessous[b,c,f,2,*]

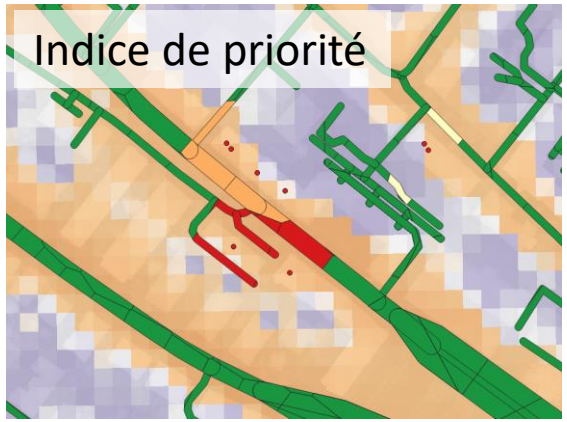
[a] Laboratory of Geographic Information Systems (LASIG), School of Architecture, Civil and Environmental Engineering (ENAC), Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland
[b] Unit of Population Epidemiology, Division of Primary Care Medicine, Department of Community Medicine, Primary Care and Emergency Medicine, Geneva University Hospitals, Geneva, Switzerland
[c] GIRAPH Lab (Geographic information for research and analyses in public health), Switzerland
[d] Center for Investigation and Research in Sleep, Lausanne University Hospital (CHUV) and Lausanne University, Lausanne, Switzerland
[e] Department of Medicine, Internal Medicine, Lausanne University Hospital (CHUV) and Lausanne University, Lausanne, Switzerland
[f] Department for Ambulatory Care and Community Medicine, University of Lausanne, Lausanne, Switzerland
[g] Department of Psychiatry, Lausanne University Hospital and Lausanne University, Lausanne, Switzerland



Setting priorities between neighborhoods

Where are the more exposed neighborhoods: hotspots with the highest dB(a) mean values



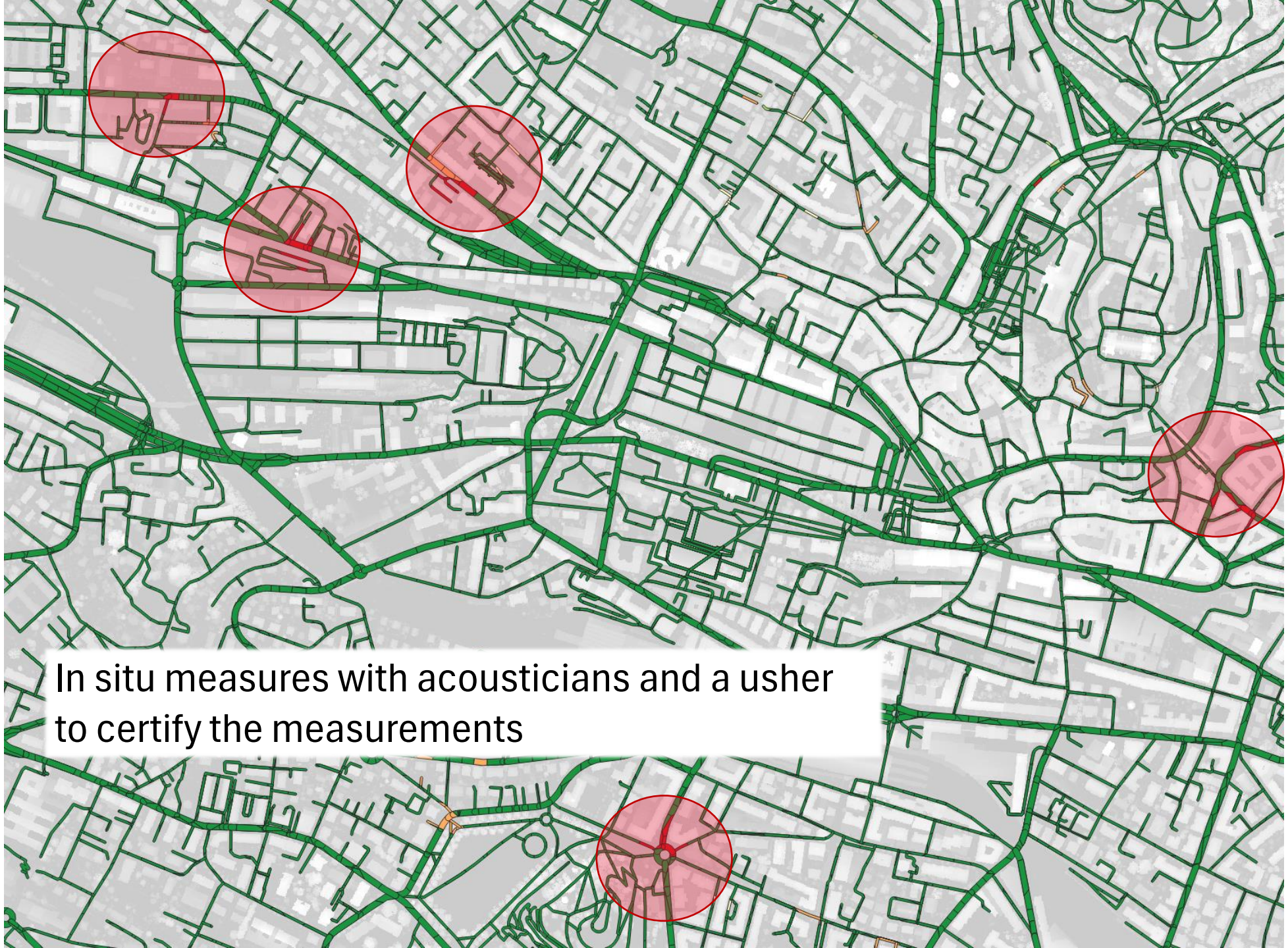


Catégorie LISA
- Not significant
- High-High
- Low-Low
- Low-High
- High-Low

Bruit Nocturne [dB]
- 9.6621 - 23.3974
- 23.3974 - 37.1326
- 37.1326 - 50.8679
- 50.8679 - 64.6032
- 64.6032 - 78.3385

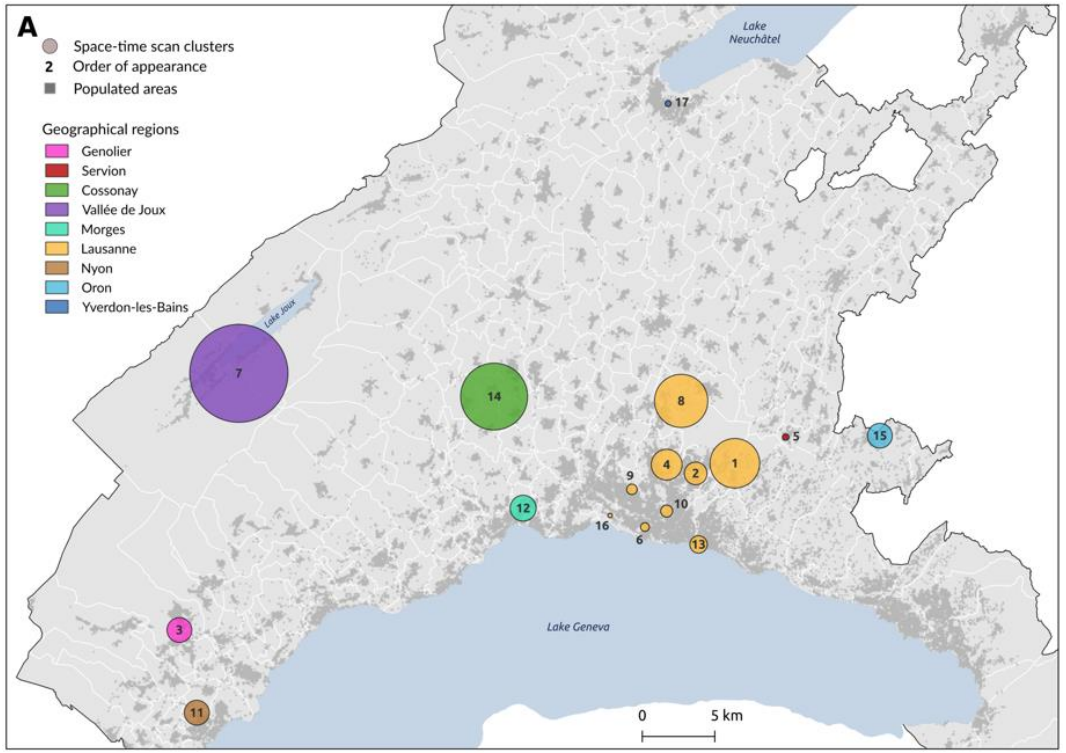
rues_prioritaires_lsne :: Features Total: 40091, Filtered: 40091, Selected: 0

	ID_adr	type	axSpe	STRNAME	DEINR	PLZ4	priority	H16PTOT	night_mean	night_max
1	9439	pe...	0,0...	Rue Jenny-Enning	1	1003	0,997...	111	62,81865934892...	65,00013732910...
2	9439	pe...	0,0...	Rue Jenny-Enning	1	1003	0,997...	111	62,81865934892...	65,00013732910...
3	9439	sec...	50,...	Rue Jenny-Enning	1	1003	0,997...	111	62,81865934892...	65,00013732910...
4	9439	sec...	50,...	Rue Jenny-Enning	1	1003	0,997...	111	62,81865934892...	65,00013732910...
5	9439	sec...	50,...	Rue Jenny-Enning	1	1003	0,997...	111	62,81865934892...	65,00013732910...
6	4416	sec...	50,...	Rue Caroline	8	1003	0,989...	92	62,66678206125...	64,00010681152...
7	6722	un...	30,...	Route de Chavannes	5	1007	0,983...	16	62,53676716874...	73,00000762939...
8	6722	pe...	0,0...	Route de Chavannes	5	1007	0,983...	16	62,53676716874...	73,00000762939...
9	6722	pe...	0,0...	Route de Chavannes	5	1007	0,983...	3	62,53676716874...	73,00000762939...
10	6722	ser...	0,0...	Route de Chavannes	5	1007	0,983...	3	62,53676716874...	73,00000762939...
11	6722	ser...	0,0...	Route de Chavannes	5	1007	0,983...	3	62,53676716874...	73,00000762939...
12	6722	ser...	0,0...	Route de Chavannes	5	1007	0,983...	3	62,53676716874...	73,00000762939...
13	6722	ser...	0,0...	Route de Chavannes	5	1007	0,983...	3	62,53676716874...	73,00000762939...
14	6722	pri...	50,...	Route de Chavannes	5	1007	0,983...	3	62,53676716874...	73,00000762939...
15	6722	pri...	50,...	Route de Chavannes	5	1007	0,983...	3	62,53676716874...	73,00000762939...
16	6722	pri...	50,...	Route de Chavannes	5	1007	0,983...	3	62,53676716874...	73,00000762939...


In situ measures with acousticians and a usher
to certify the measurements


La Sou
l' Clinique
RTS INFO
LE 19 30

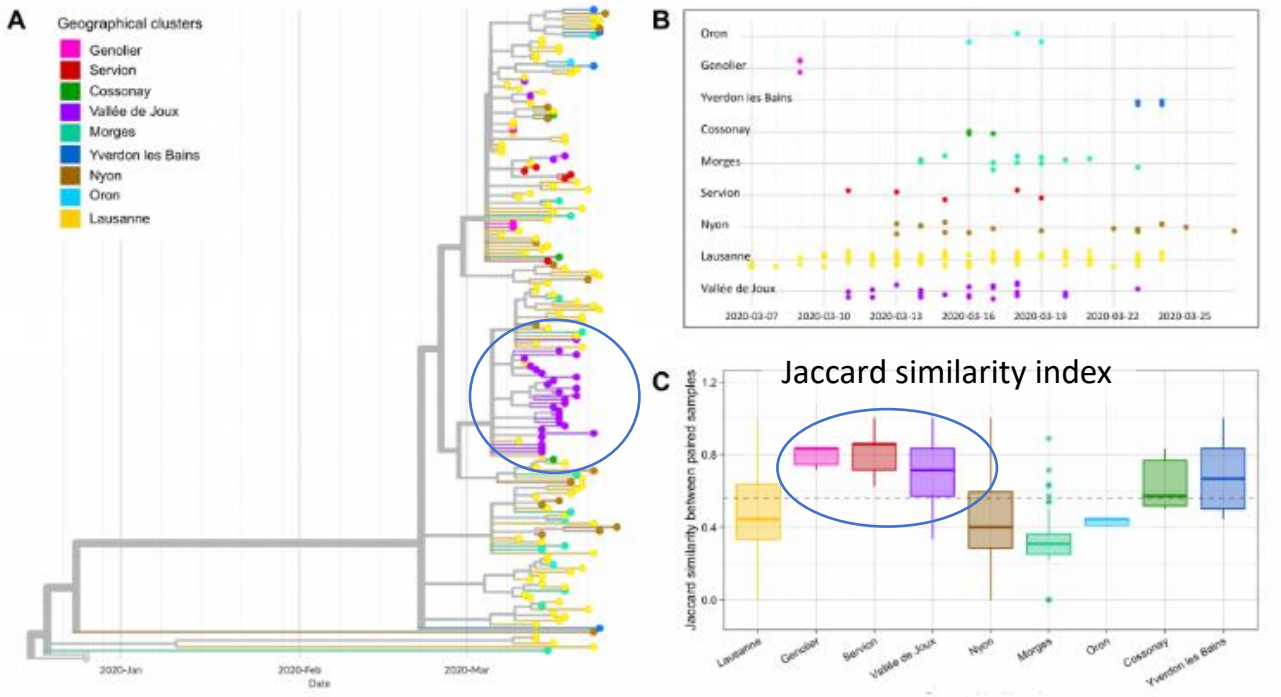
GIS for the genomic characterization of spatial clusters of SARS-COV-2



Choi et al. 2022

Sequencing of SARS-CoV-2 positive samples

Choi et al. 2022



Cluster ID (chronological)	Geographic location (urban / rural)	Cluster period	Relative risk	P-value	% of cases sequenced (n)
1	Lausanne region (u)	Mar 7-10	64.51	4e-6	87.5 (7)
2	Lausanne region (u)	Mar 8-14	14.64	5e-4	90.9 (10)
3	Genolier (r)	Mar 3-17	17.09	0.794	60.0 (3)
4	Lausanne region (u)	Mar 10-21	6.51	2e-4	60.0 (12)
5	Servion (r)	Mar 11-20	40.11	0.008	83.3 (5)
6	Lausanne region (u)	Mar 11-24	3.07	0.986	86.7 (13)
7	Vallée de Joux (r)	Mar 12-23	10.50	2e-16	81.6 (31)
8	Lausanne region (u)	Mar 12-25	5.22	1e-4	84.0 (21)
9	Lausanne region (u)	Mar 13-23	5.22	0.020	16.7 (3)
10	Lausanne region (u)	Mar 13-24	5.28	0.002	90.5 (19)
11	Nyon (u)	Mar 14-27	4.47	0.010	72.7 (16)
12	Morges (u)	Mar 15-23	5.65	0.035	75.0 (12)
13	Lausanne region (u)	Mar 15-28	5.10	0.004	23.8 (5)
14	Cossonay (r)	Mar 16-22	8.19	0.005	21.4 (3)
15	Oron (r)	Mar 16-29	6.38	0.232	25.0 (3)
16	Lausanne region (u)	Mar 17-30	207.53	4e-6	83.3 (5)
17	Yverdon-les-Bains (u)	Mar 24-25	27.35	0.045	66.7 (4)

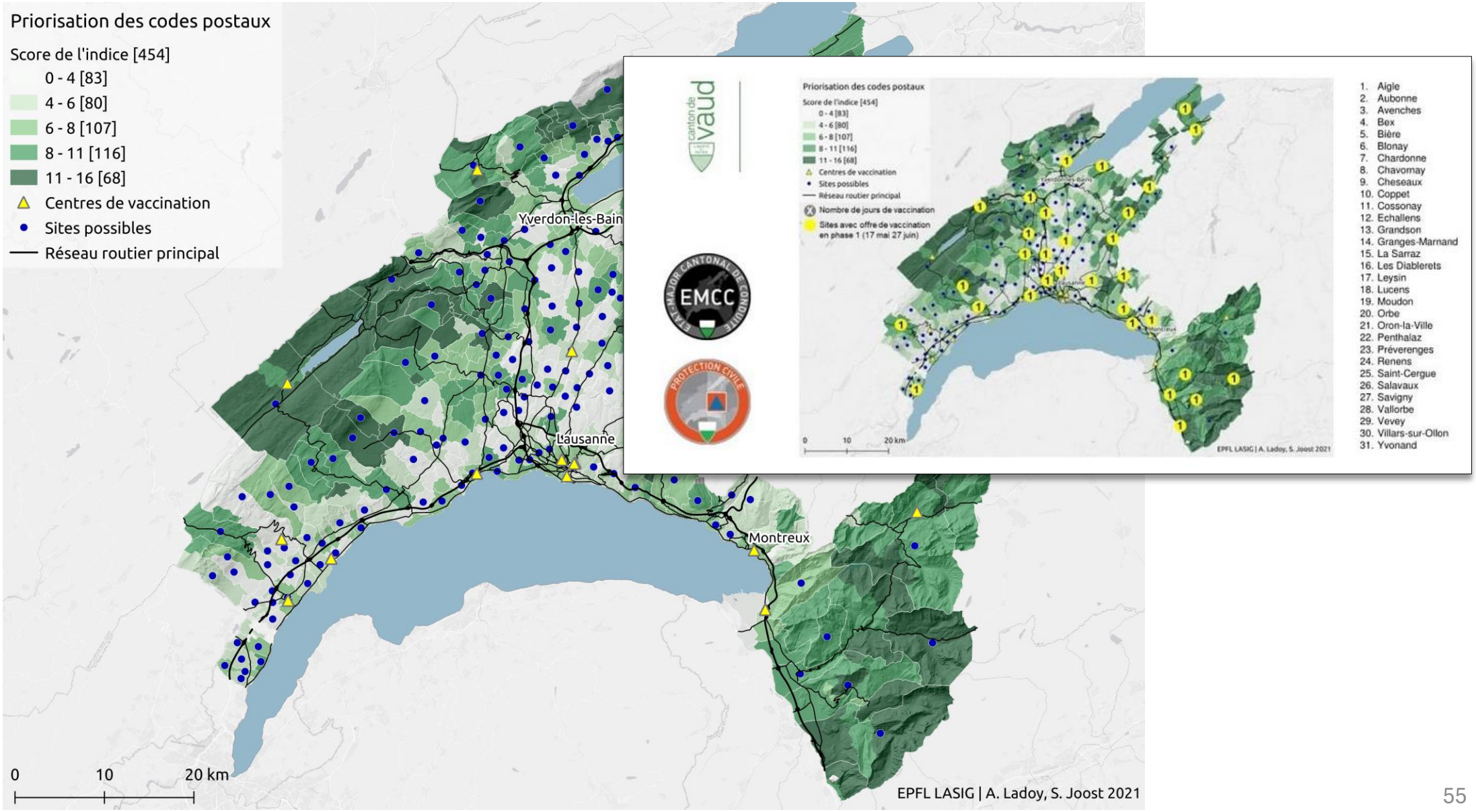
- Collaboration with Institute of Microbiology at CHUV
- Public health surveillance by combining geospatial clustering and genomic analysis
- A powerful approach to detect high-incidence areas where authorities could decide on local lockdown, prioritize cases for genome sequencing and contact tracing

SARS-COV-2 Vaud mobile vaccination campaign

- Set up mobile vaccination centers for the most vulnerable populations
- Working group with head of Civil Protection VD, vaccination expert (DGS), DGS communication manager
- Three types of criteria: i) Accessibility, ii) Socio-eco vulnerability iii) Health vulnerability (immunity level based on the proportion of positive tests and vaccinated people)
- Multi-criteria weighting based on expert opinion

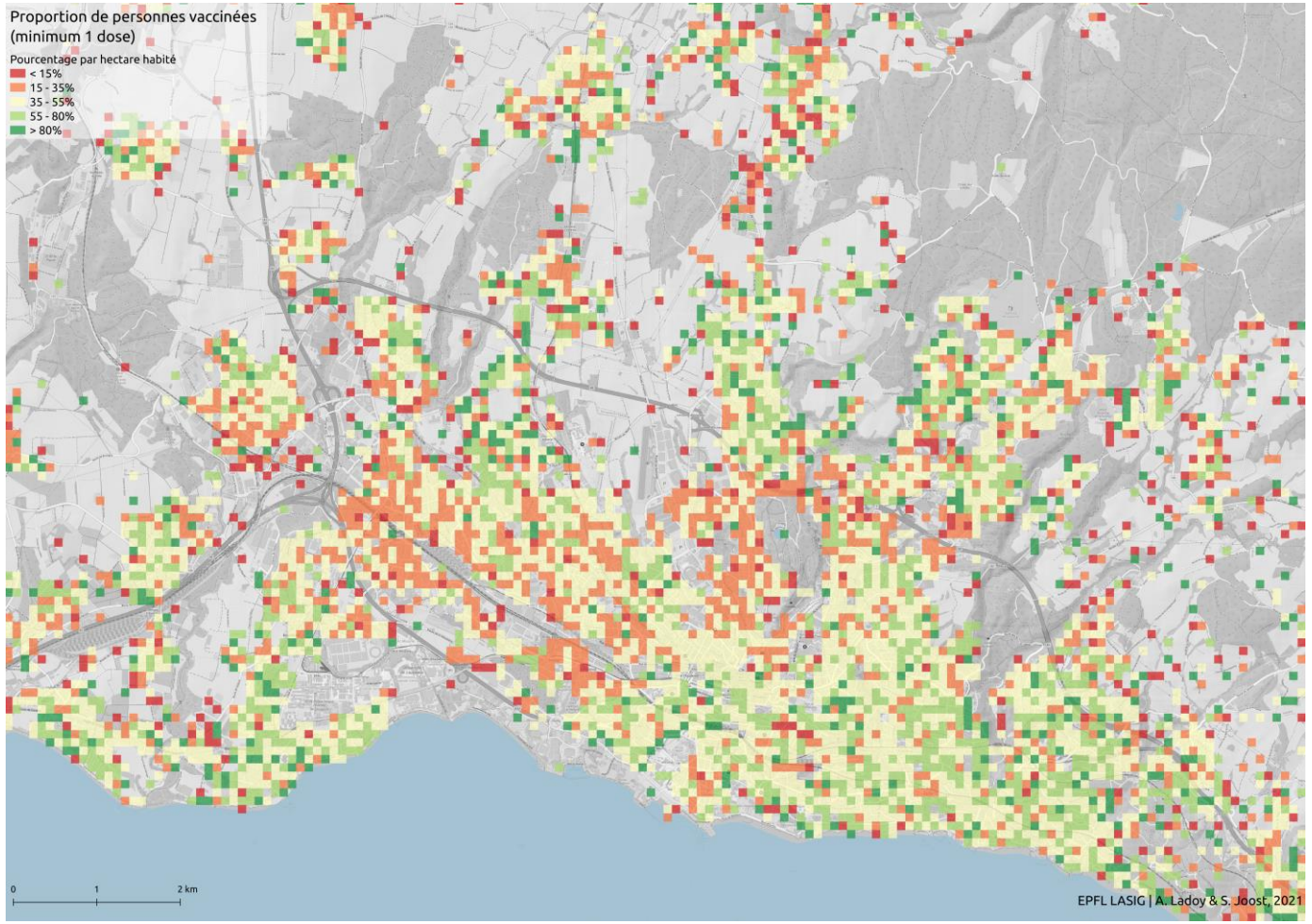
NOM	*DESCRIPTION*
Accessibilité aux services de vaccination	
pt_stops	Nombre d'arrêts des transports publics / hectare habité
all_vacc_ctrs	Nombre de centres de vaccination toutes catégories confondues (cabinets médicaux, pharmacies, centres) / 1000 habitants
nrst_vacc_ctr_dist	Distance en voiture au centre de vaccination le plus proche [m]
Vulnérabilité socio-économique	
ciqmd	Revenu médian annuel en kCHF
rpcsp3	Proportion d'habitants dans la catégorie socio-professionnelle inférieure (non qualifiés)
rp65m	Proportion de 65 ans et plus
opla	Proportion de 65 ans et plus vivant seuls
Vulnérabilité sanitaire	
covid19_cases	Nombre de tests positifs / 1000 habitants
vaccination	Nombre de personnes vaccinées / 1000 habitants

SARS-COV-2 Mobile Vaccination phase 1 NPA

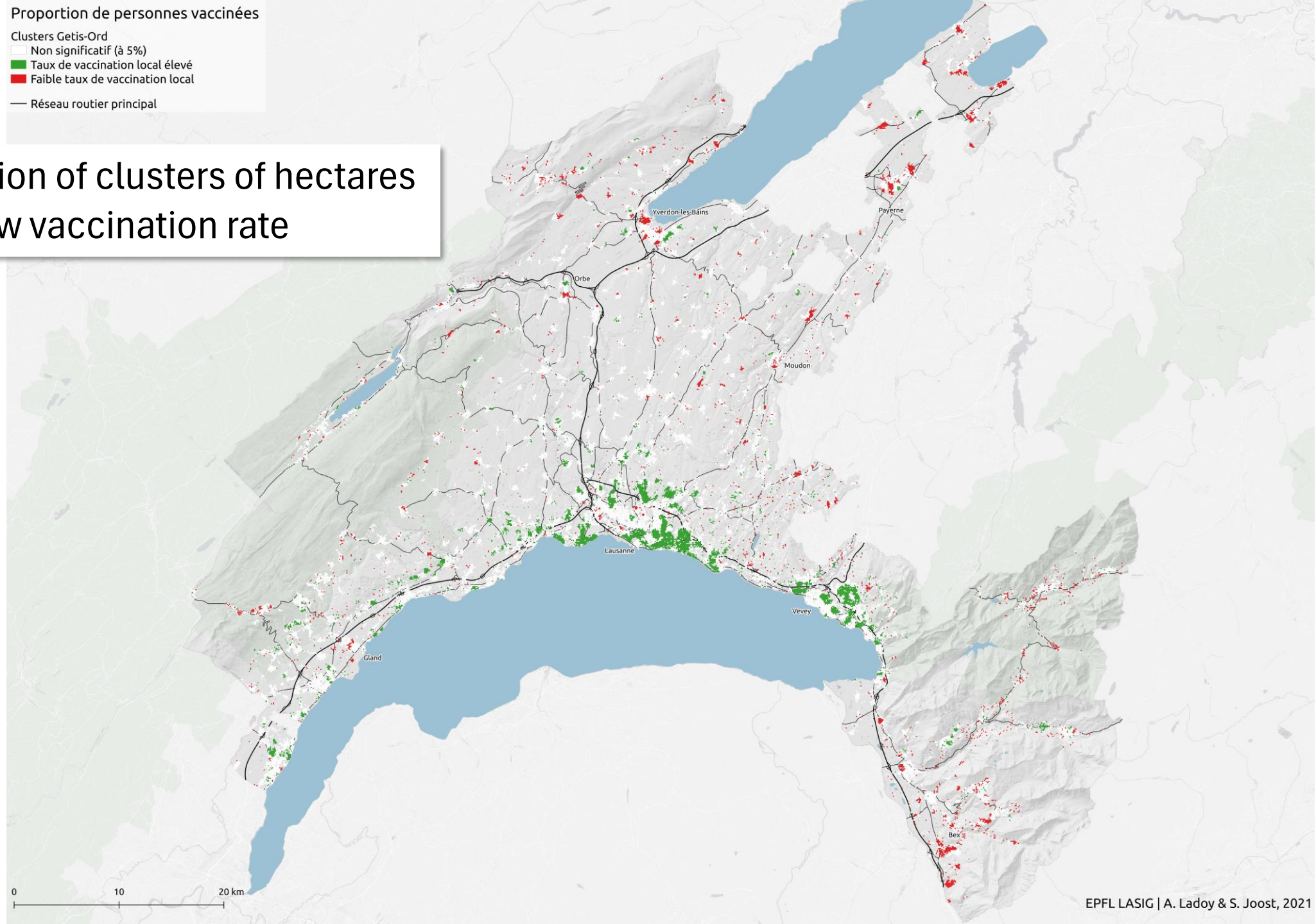


SARS-COV-2 Mobile Vaccination phase 2 Hectare

- Tighten the meshes of the net
- Target vulnerable populations in hectares where a low rate of "eligible" pop is vaccinated (1 dose)
- Ref: cantonal average = 40% of the population vaccinated in June 2021

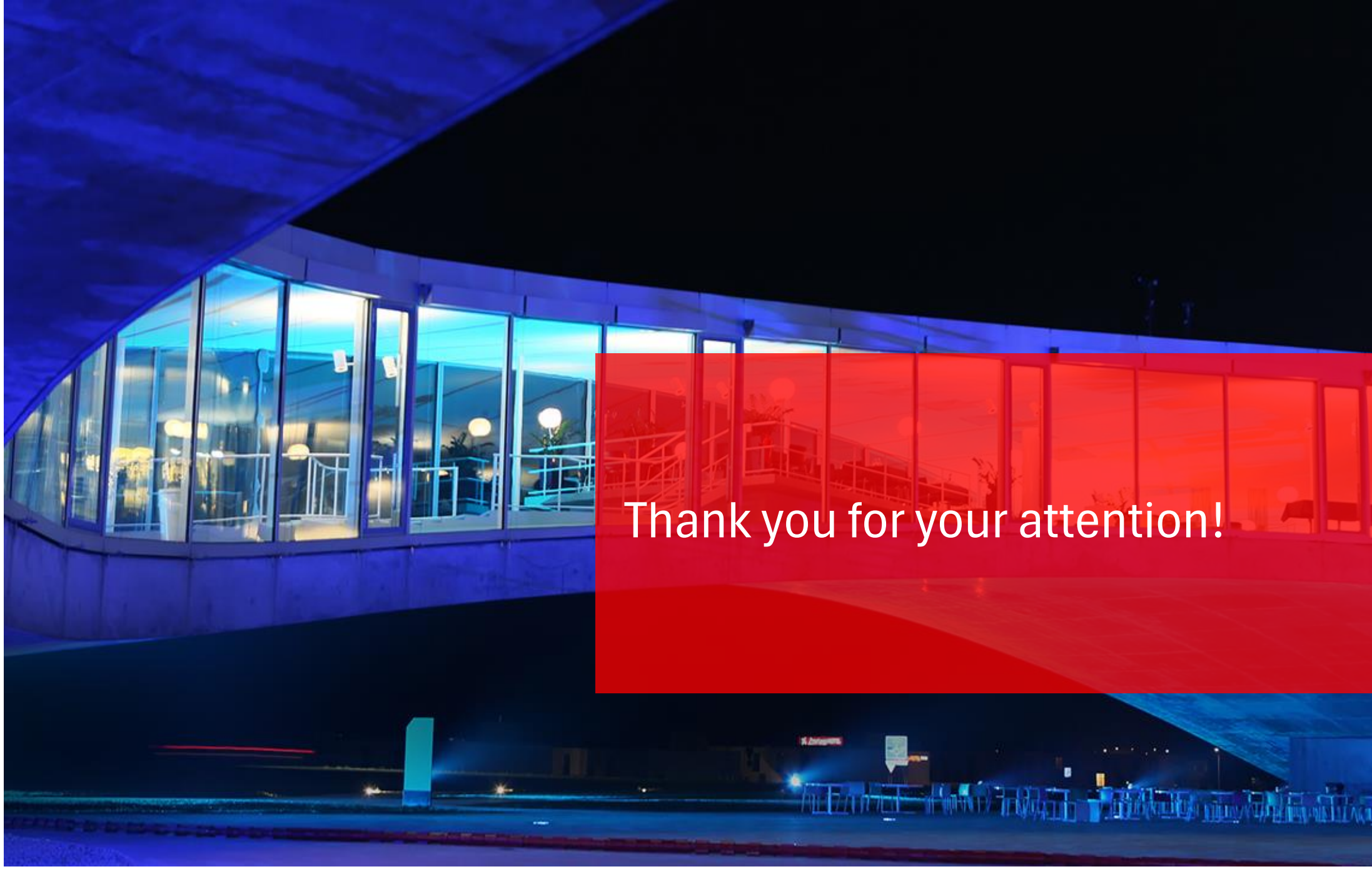


Detection of clusters of hectares with low vaccination rate



Conclusion

- With our research and training work in SIE/EPFL we can have a concrete impact on the society (e.g. GENMON for genetic resources; noise and speed reduction, COVID vaccination for public health)
- Many studies in VD and GE: on BMI (Guessous et al. 2014; Joost et al. 2016), nutrition (Joost et al. 2019; de Ridder et al. 2021), sleep disorders (Joost et al. 2018), physical activity (Vallarta-Robledo et al. 2022), infectious diseases (Ladoy et al. 2021), etc.
- Report on the public health policy of the canton of Vaud 2018-2022, Measure No. 4 “The use of geographic information in the development of public health and prevention policy programs must be intensified” (introduction of new practices based on SIE/EPFL research)
- Dr Anaïs Ladoy, former SIE student, finished her PhD thesis in January 2024 (funded by Direction Générale de la Santé, state of Vaud) and was directly hired by the state (she is now the person responsible for GIS and spatial epidemiology at the DGS Vaud)


Thank you for your attention!

GIS Exercise

- You will use your own computers to run the exercise
- Before **Monday, October 14**, you need to install two software:
  - QGIS, version 3.34 LTR → https://www.qgis.org/download/
  - Geoda, version 1.22.08 → https://geodacenter.github.io/download.html

  Both software are available on Windows, MacOS and Linux

- You can also use the ENAC-SSIE virtual environment where QGIS and Geoda are already installed: https://vdi.epfl.ch/portal/webclient/#/home
- On the VDI, the software can be found here:
  Applications (shortcut on the desktop)>APP-SSIE-LASIG
- The exercise statement and the data will be made available on Moodle