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TAKING THE PULSE OF OUR PLANET FROM SPACE

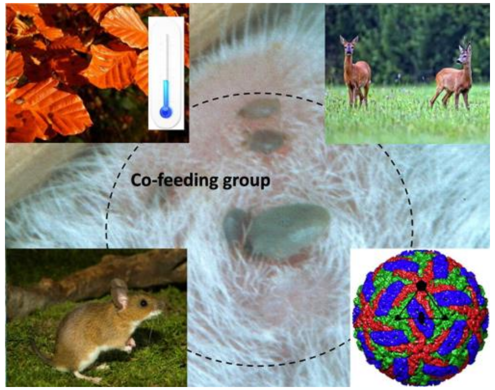
Identifying the most relevant covariates for the development of tick-borne encephalitis (TBE) hazard models at continental scale

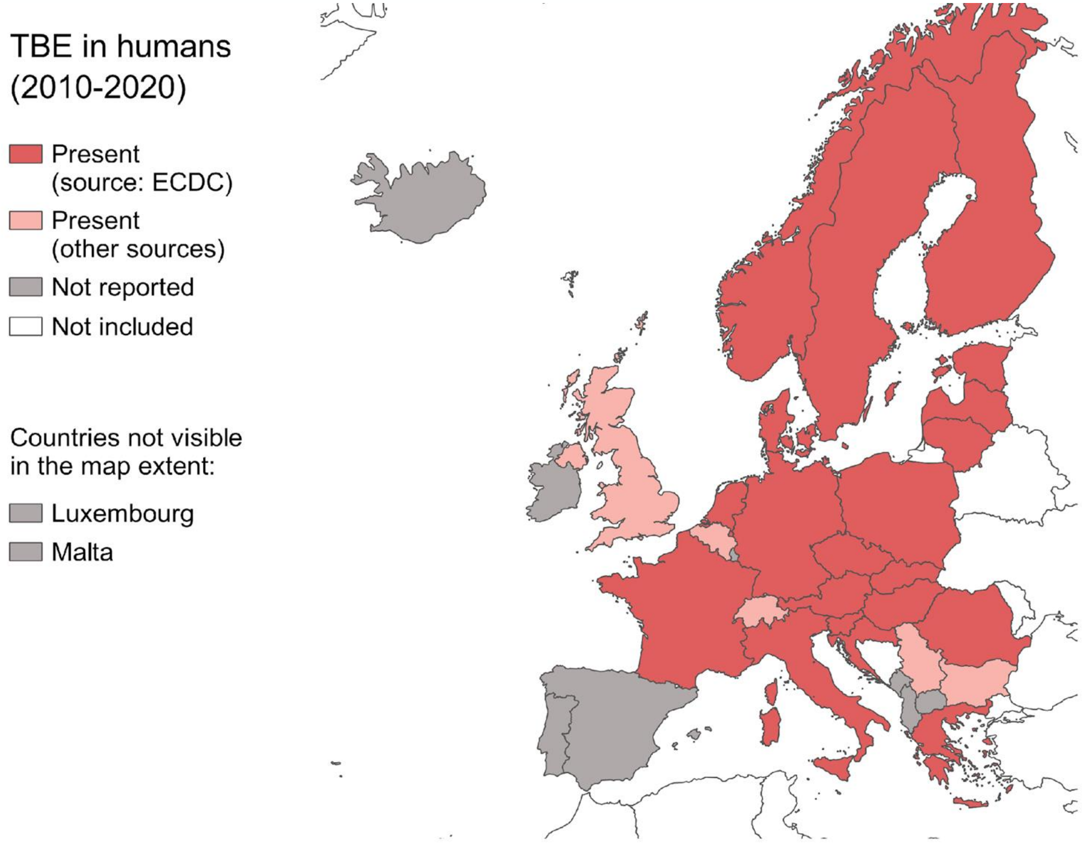
Francesca Dagostin, Valentina Tagliapietra, Giovanni Marini, Claudia Cataldo, Maria Bellenghi, Scilla Pizzarelli, William Wint, Neil S. Alexander, Markus Neteler, Julia Haas, Duccio Rocchini, Marco Cervellini, Timothée Dub, Luca Busani, Annapaola Rizzoli

24. May 2022

Tick-borne encephalitis (TBE)

- Tick-borne encephalitis (TBE) is a human viral infectious disease involving the central nervous system and occurring in many parts of Europe and Asia.
- Transmission to humans occurs through the bite of infectious ticks or, less frequently, through the consumption of unpasteurized milk and milk products.
- Endemic in at least 27 European countries, causing more than 2,000 reported cases each year. In 2019 TBE incidence increased from 0.6/100.000 inhabitants (average value from 2016-2018) to 0.7 per 100.000 (Source: ECDC).
- TBE spatial distribution is showing altitudinal and longitudinal shifts. New foci are emerging in non-endemic countries.
- The virus circulates in nature among ticks mostly belonging to the *Ixodes ricinus* complex and wildlife hosts.

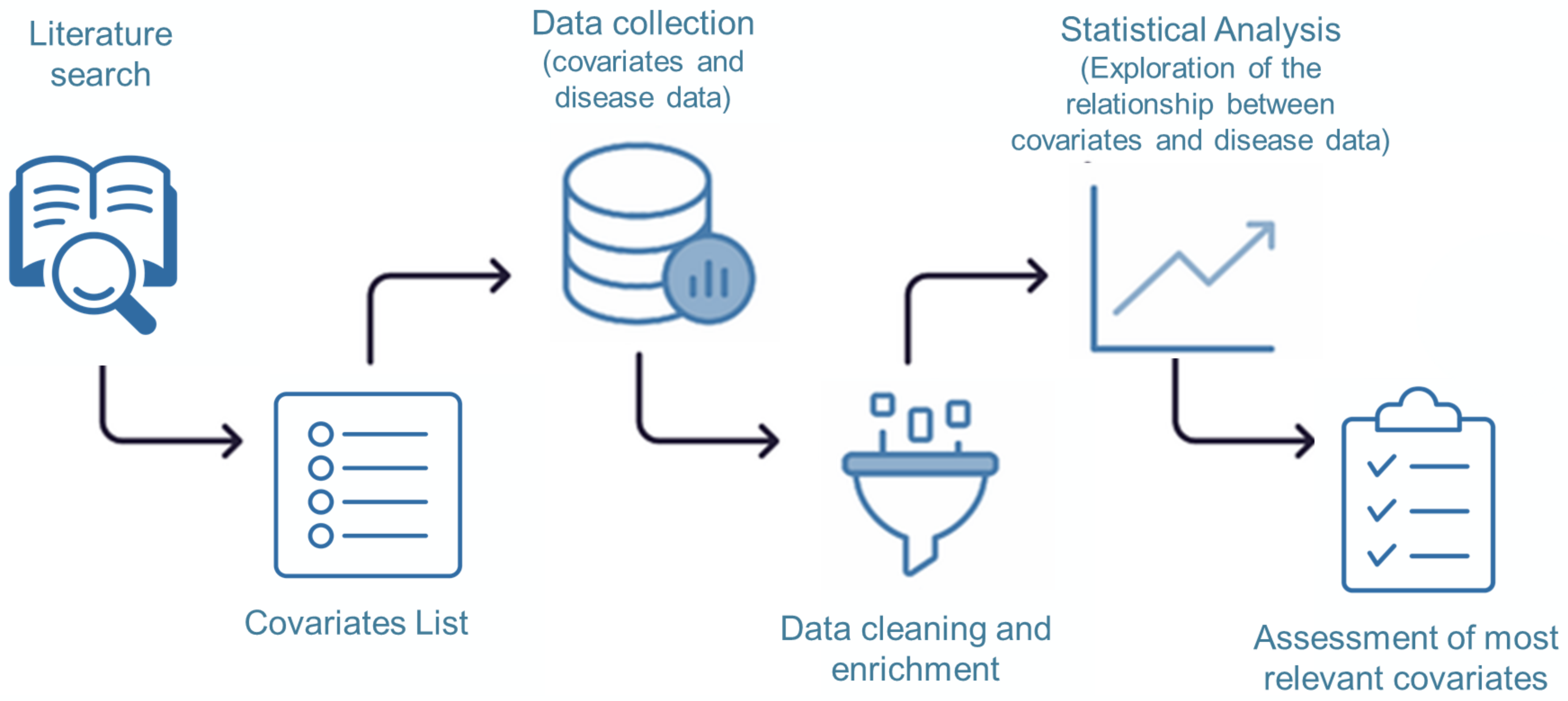




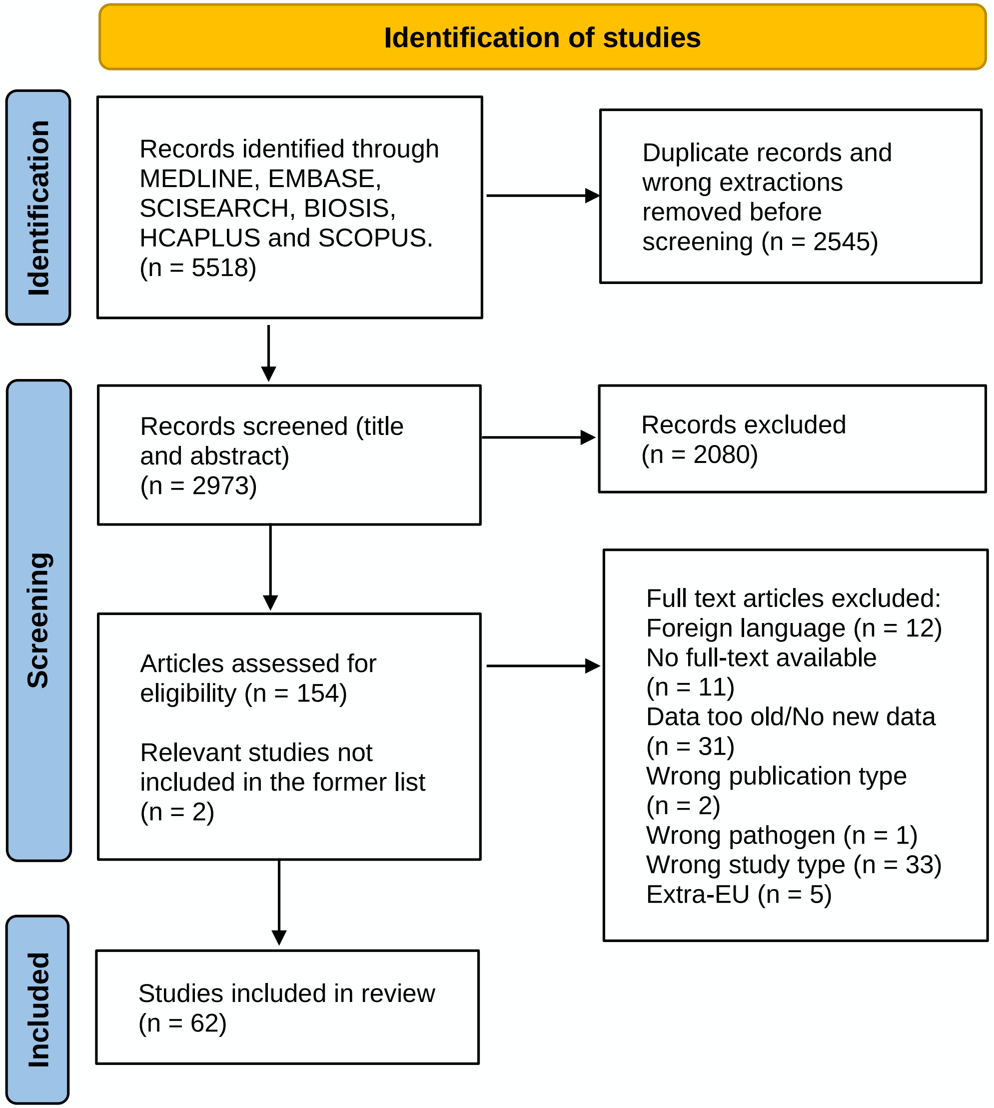
Our scientific question:

What are the environmental and ecological factors affecting the risk of tick-borne encephalitis in Europe?

Workflow


Literature search
Data collection (covariates and disease data)
Statistical Analysis (Exploration of the relationship between covariates and disease data)
Covariates List
Data cleaning and enrichment
Assessment of most relevant covariates

1. Literature screening



1. Literature screening

Identification of studies

Identification

Records identified through MEDLINE, EMBASE, SCISEARCH, BIOSIS, HCAPLUS and SCOPUS. (n = 5518)

Duplicate records and wrong extractions removed before screening (n = 2545)

Screening

Records screened (title and abstract) (n = 2973)

Records excluded (n = 2080)

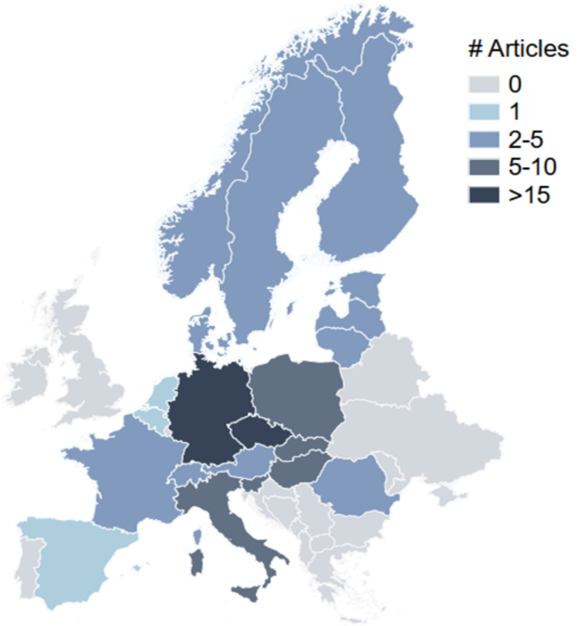
Articles assessed for eligibility (n = 154)

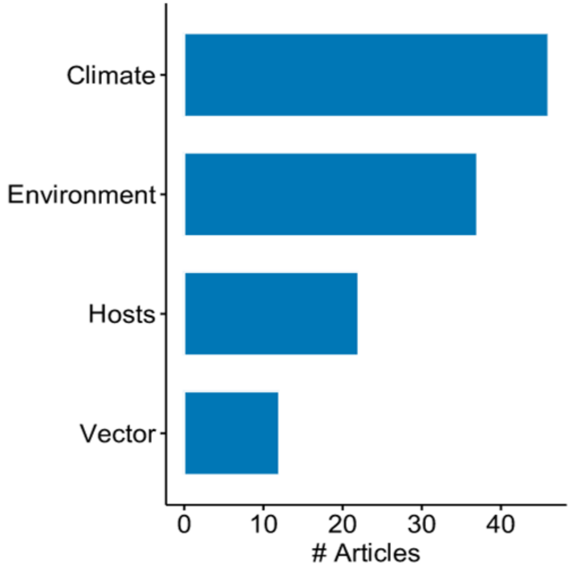
Relevant studies not included in the former list (n = 2)

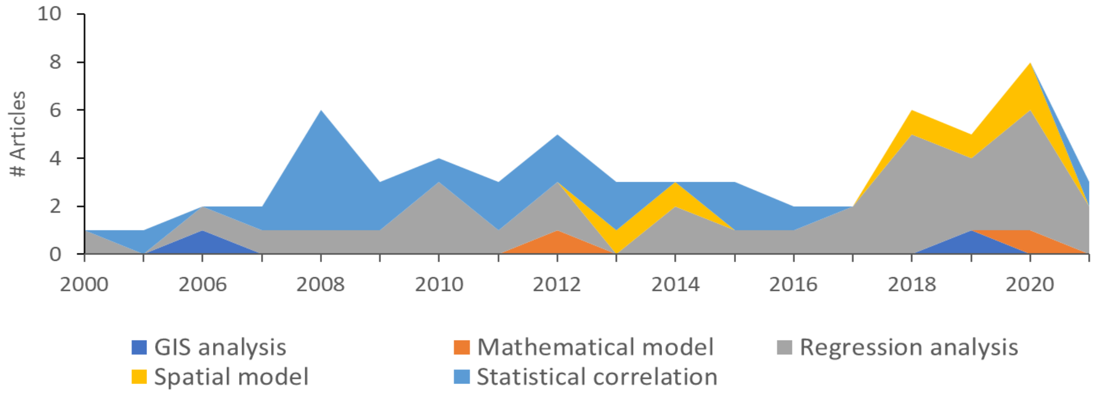
Full text articles excluded:
Foreign language (n = 12)
No full-text available (n = 11)
Data too old/No new data (n = 31)
Wrong publication type (n = 2)
Wrong pathogen (n = 1)
Wrong study type (n = 33)
Extra-EU (n = 5)

Included

Studies included in review (n = 62)

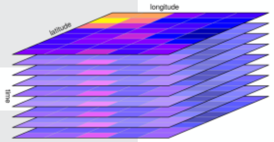






2. Data collection and processing: covariates data

kindly provided by ERGO Oxford Group, Mundialis GmbH & Co. and Prof. Duccio Rocchini, UniBo



CLIMATIC VARIABLES	SOURCES
Mean winter temperature (°C)	MODIS LST (NASA)
Autumnal cooling rate	MODIS LST (NASA)
Spring warming rate	MODIS LST (NASA)
Annual mean temperature (°C)	MODIS LST (NASA)
Annual mean diurnal temp. range (°C)	MODIS LST (NASA)
Isothermality (%)	MODIS LST (NASA)
Temperature seasonality %)	MODIS LST (NASA)
Min temp. of coldest month (°C)	MODIS LST (NASA)
Mean temp. of wettest quarter (°C)	MODIS LST (NASA)
Mean temp. of driest quarter (°C)	MODIS LST (NASA)
Mean temp. of warmest quarter (°C)	MODIS LST (NASA)
Mean temp. of coldest quarter (°C)	MODIS LST (NASA)
Annual total precipitation (mm)	ECMWF ERA5-Land (C3S)
Precipitation seasonality (%)	ECMWF ERA5-Land (C3S)
Total prec. of wettest quarter (mm)	ECMWF ERA5-Land (C3S)
Total prec. of driest quarter (mm)	ECMWF ERA5-Land (C3S)
Total prec. of warmest quarter (mm)	ECMWF ERA5-Land (C3S)
Total prec. of coldest quarter (mm)	ECMWF ERA5-Land (C3S)
Annual mean relative humidity (%)	ERA5-Land; Metz et al., 2022.
Mean saturation deficit	ERA5-Land; Metz et al., 2022.

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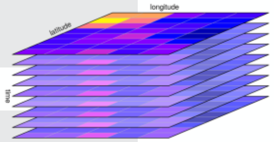
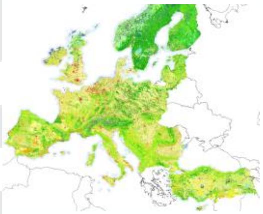


ENVIRONMENTAL VARIABLES	SOURCES
% of forest area (class 3.1)	Corine LandCover (EEA)
% of low vegetation area (class 3.2)	Corine LandCover (EEA)
% of agricultural land (class 2)	Corine LandCover (EEA)
% of urban area (class 1)	Corine LandCover (EEA)
% of area covered by snow	Consensus land-cover product
Length of forest roads (km)	Open Street Maps
Enhanced Difference Vegetation Index (EVI)	MODIS EVI (NASA)
Mean elevation	Global Multi-resolution Terrain Elevation Dataset



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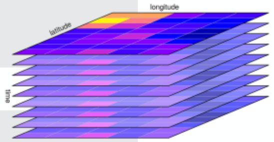

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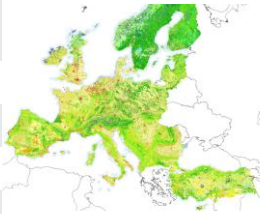
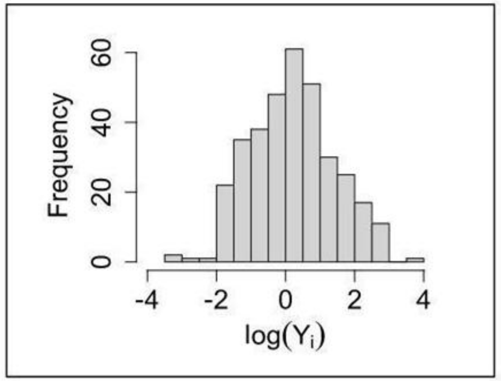


HOSTS AND VECTOR VARIABLES	SOURCES
Deer (C. capreolus, C. elaphus, D. dama) probability of presence*	ERGO Oxford Group
Rodent (A. flavicollis) probability of presence*	ERGO Oxford Group
Rodent (M. glareolus) probability of presence*	ERGO Oxford Group
Vector (I. ricinus) probability of presence*	ERGO Oxford Group
Standardized habitat richness index	Cervellini at al.**

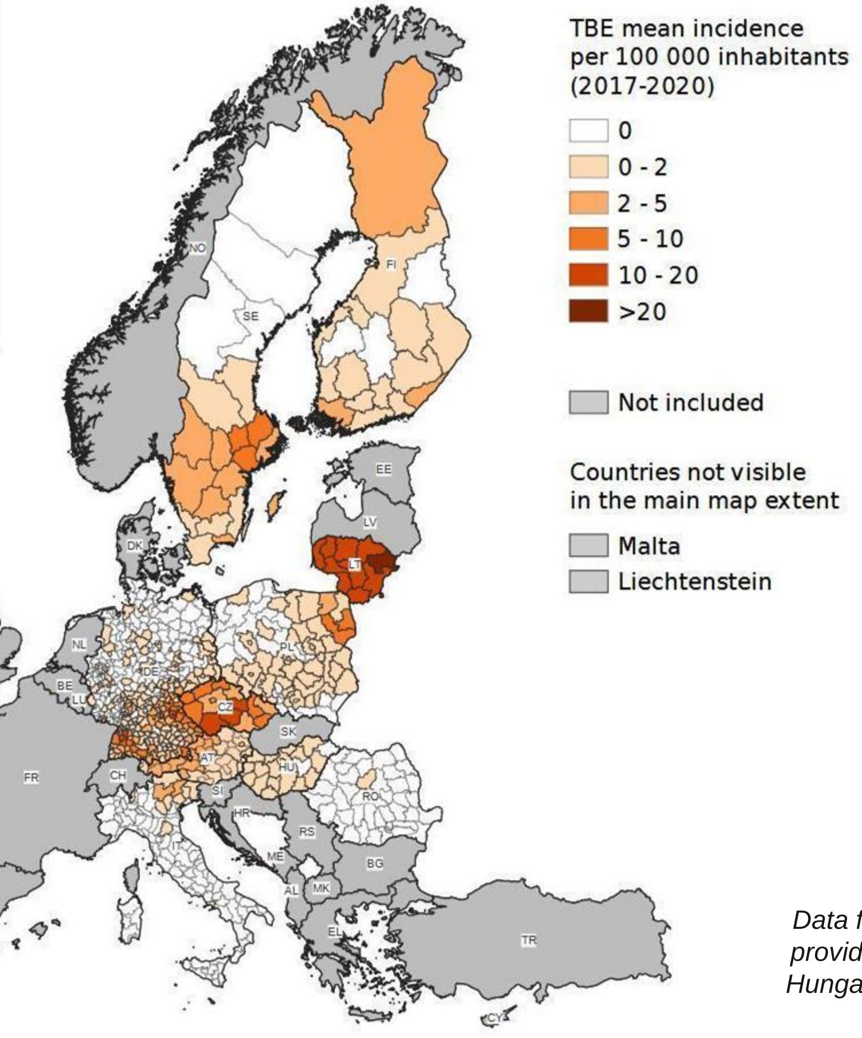
* proxies for species density
** used in this study for the first time to assess the effect of biodiversity

3. Data collection and processing: disease data

kindly provided by ECDC (TESSy)



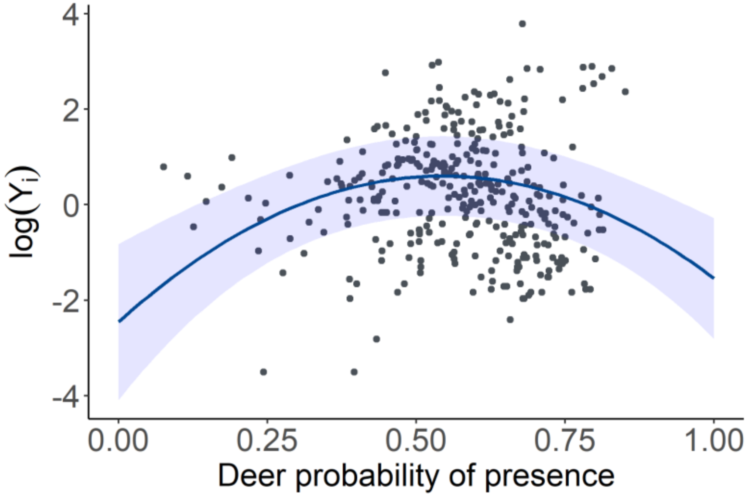
Time span:
2017-2020

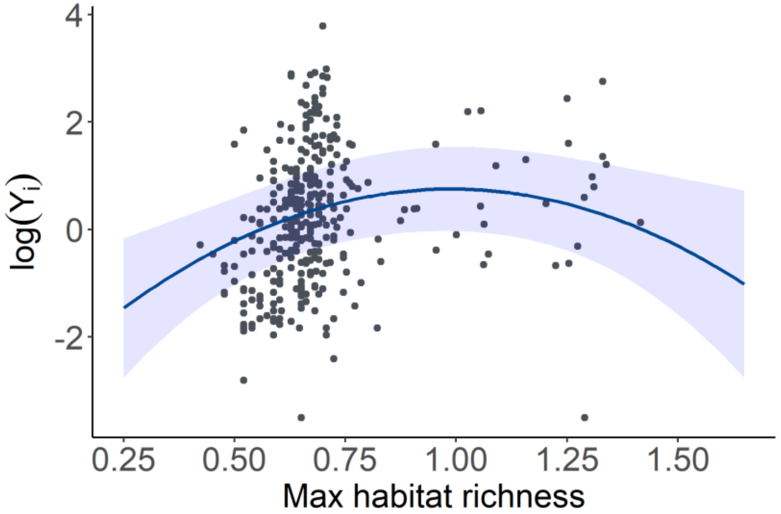


Data from The European Surveillance System – TESSy, provided by Austria, Czech Republic, Finland, Germany, Hungary, Italy, Lithuania, Poland, Romania, Sweden and released by ECDC

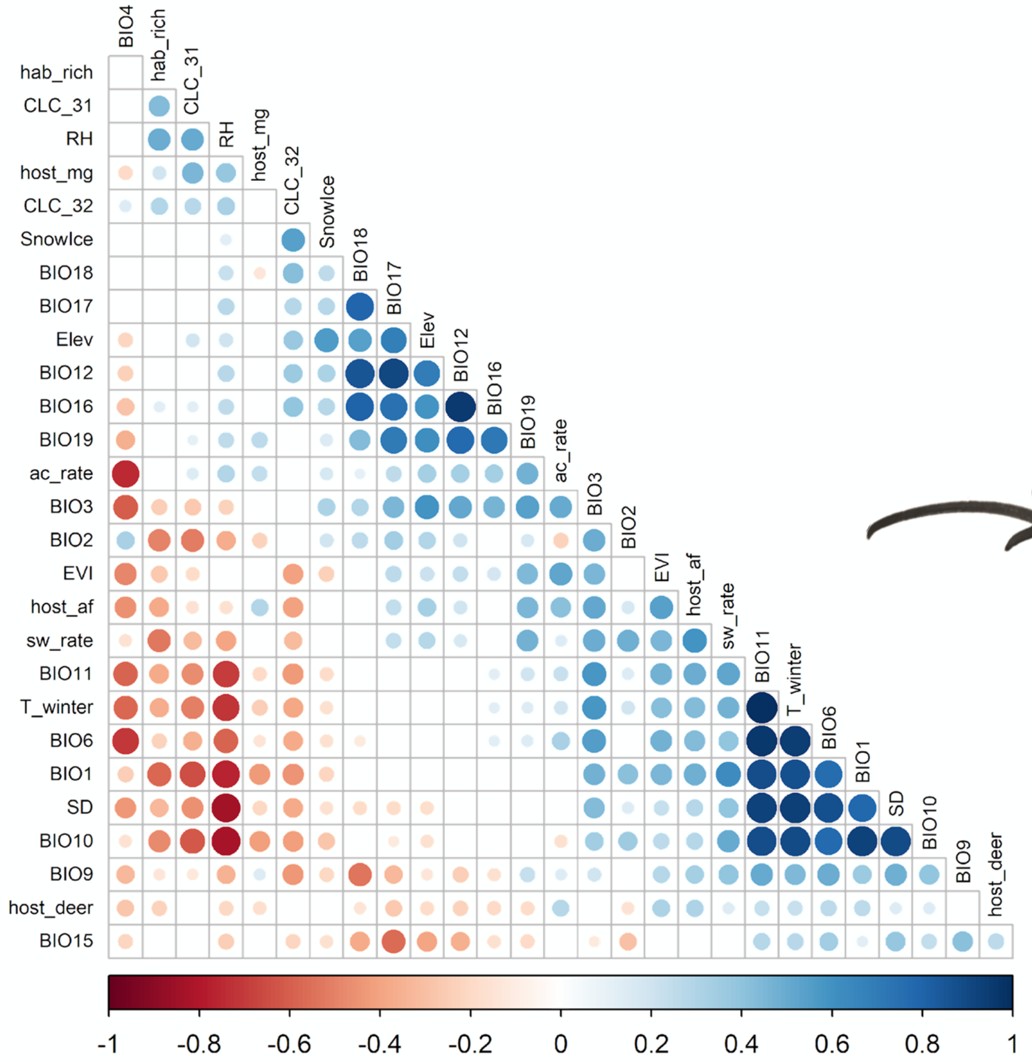
3. Single-variable statistical analysis

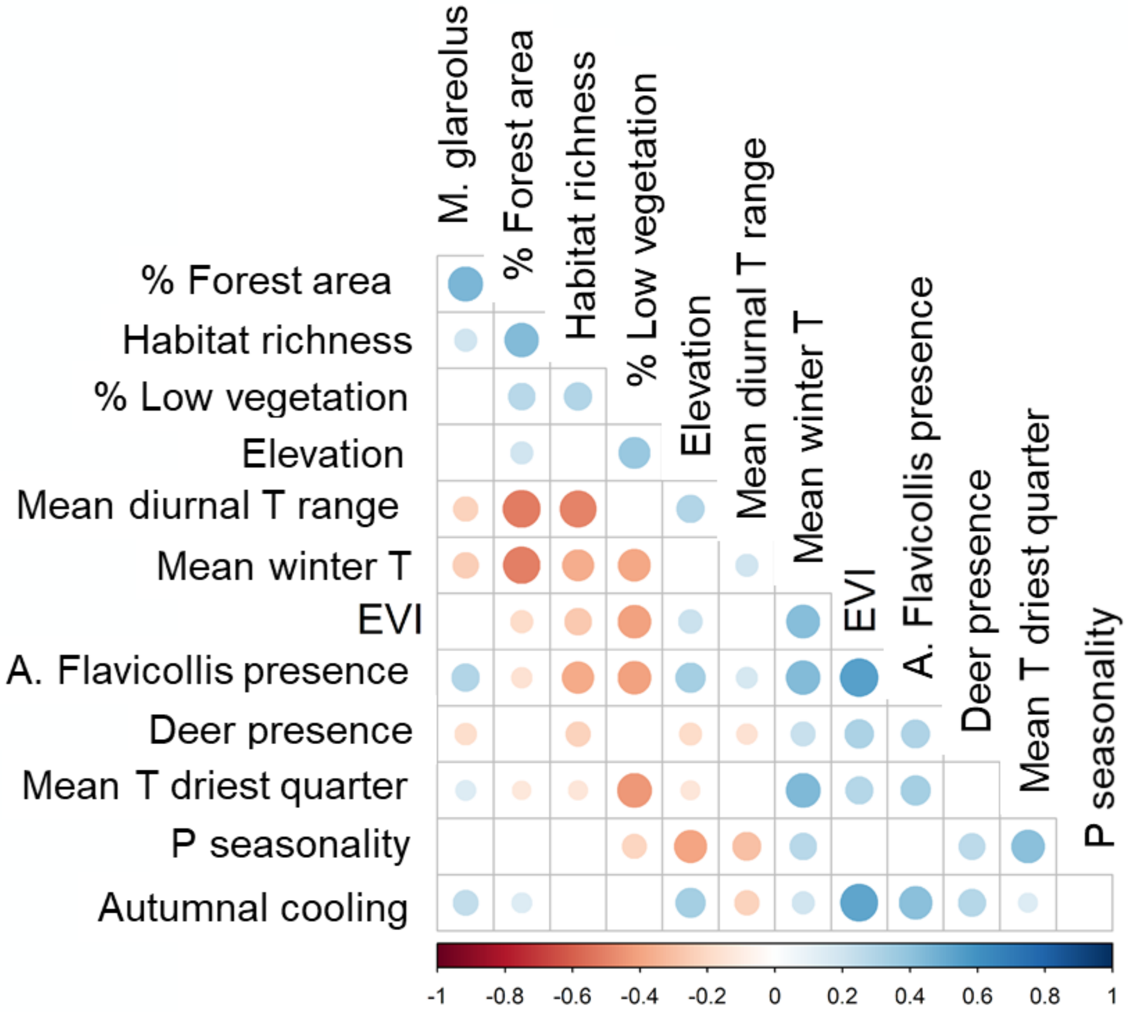
Predictors	Best model	Intercept (a_0)	p (a_0)	Linear coeff. (a_1)	p (a_1)	Quadratic coeff. (a_2)	p (a_2)	AIC
Mean winter T	Q	0·27	0·41	-0·269	<0·001	-0·013	<0·001	879·98
Elevation	Q	0 ·44	0·37	2·618	<0·001	-1·204	<0·001	890·73
Mean T coldest quarter	Q	0·27	0·41	-0·27	<0·001	-0·016	<0·001	905·06
Saturation Deficit	L	0·12	0·73	-2·856	<0·001	NA	NA	905·42
Mean T warmest quarter	Q	0·47	0·17	-0·228	<0·001	-0·027	<0·001	919·55
Min T coldest month	Q	0·34	0·33	-0·176	<0·001	-0·011	<0·001	919·61
% Forest area	L	-0·67	0·13	2·648	<0·001	NA	NA	925·96
Annual total P	Q	0·45	0·34	0·002	<0·001	0	0·0045	931·08
% Urban area	L	0·53	0·19	-2·433	<0·001	NA	NA	931·49
P of warmest quarter	Q	0·38	0·39	0·007	<0·001	0	0·0016	933·97
P of driest quarter	Q	0·44	0·32	0·009	<0·001	0	0·0102	934·72
Relative Humidity	Q	0·54	0·15	0·153	<0·001	-0·033	<0·001	936·87
P of wettest quarter	Q	0·40	0·4	0·006	<0·001	-0·00001	0·0223	940·93
Annual mean T	Q	0·39	0·27	-0·153	<0·001	-0·008	0·0011	941·61
P coldest quarter	L	0·45	0·3	0·005	<0·001	NA	NA	951·74
P seasonality	L	0·31	0·43	-0·029	<0·001	NA	NA	953·85
Isothermality	Q	-0·11	0·8	-0·147	<0·001	0·05	<0·001	956·05
Deer presence	Q	-2·46	<0·001	11·236	<0·001	-10·323	<0·001	959·08
Autumnal cooling	Q	-16·94	<0·001	-187·72	<0·001	-504·20	<0·001	962·01
A. Flavicollis presence	L	-0·63	0·2	1·673	0·0022	NA	NA	965·07
M. Glareolus presence	Q	-2·45	0·02	9·861	0·0023	-8·111	0·0011	965·11
T seasonality	Q	0·35	0·38	1·073	0·0025	-1·318	0·0486	965·19
Mean T driest quarter	L	0·23	0·58	-0·036	0·0025	NA	NA	965·31
% Agricultural area	Q	-0·30	0·52	3·816	0·0016	-4·403	<0·001	965·44
Max habitat richness	Q	-3·22	0·01	8·025	0·0021	-4·06	0·0046	965·68
EVI	L	-1·31	0·06	5·116	0·0037	NA	NA	966·01
% Low vegetation area	L	0·07	0·87	4·964	0·0064	NA	NA	967·01
% snow-covered area	L	0·26	0·53	74·007	0·0153	NA	NA	968·57
Mean diurnal T range	L	0·30	0·45	-0·122	0·0392	NA	NA	970·18
Mean T wettest quarter	L	0·36	0·37	-0·026	0·0614	NA	NA	970·95
Spring warming	L	-0·20	0·75	3·061	0·2477	NA	NA	973·1
Vector presence	L	-0·25	0·66	0·948	0·1422	NA	NA	972·28
Length of forest roads	L	0·28	0·49	0·0004	0·3133	NA	NA	973·42





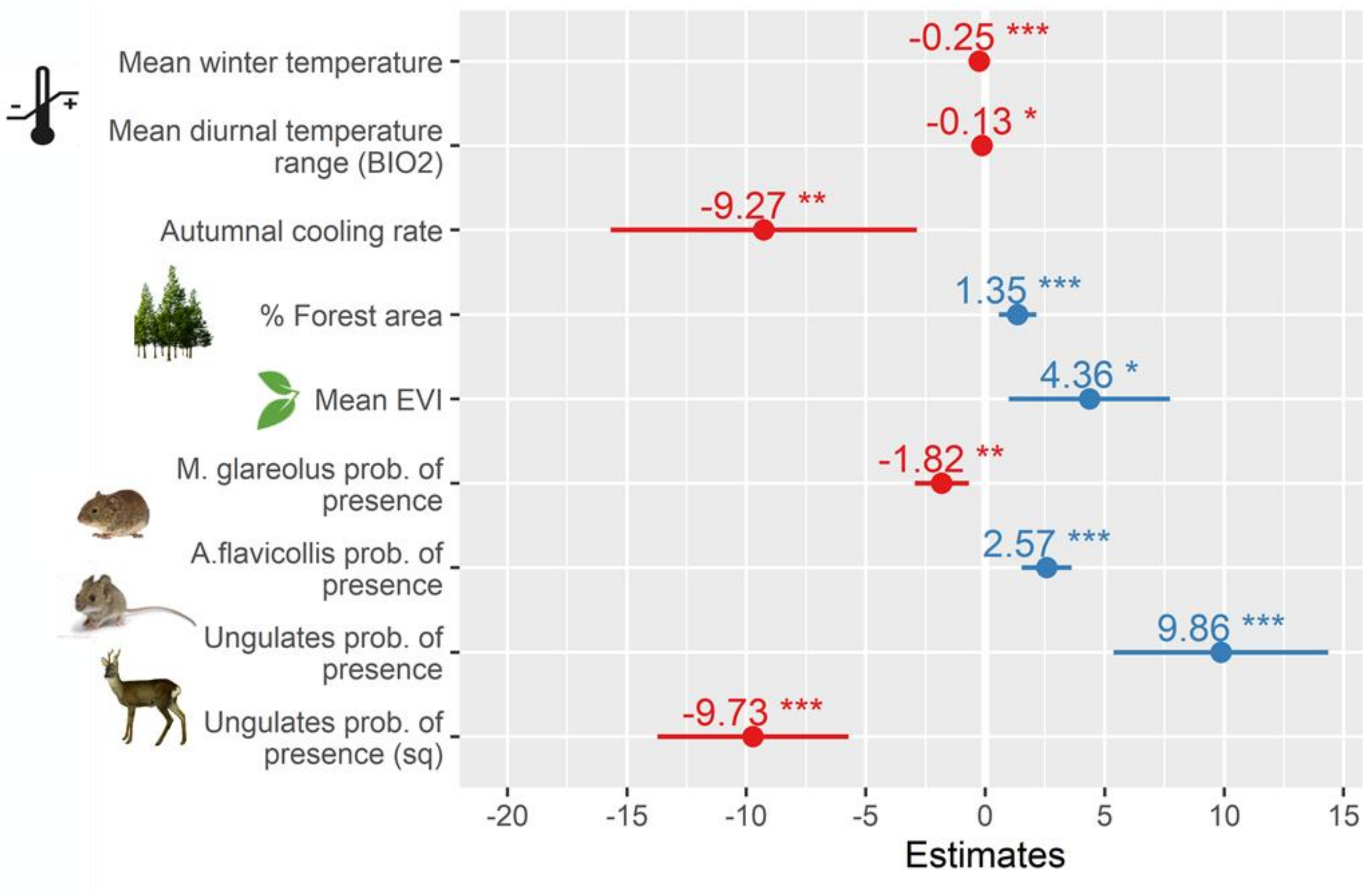
4. Multi-collinearity detection

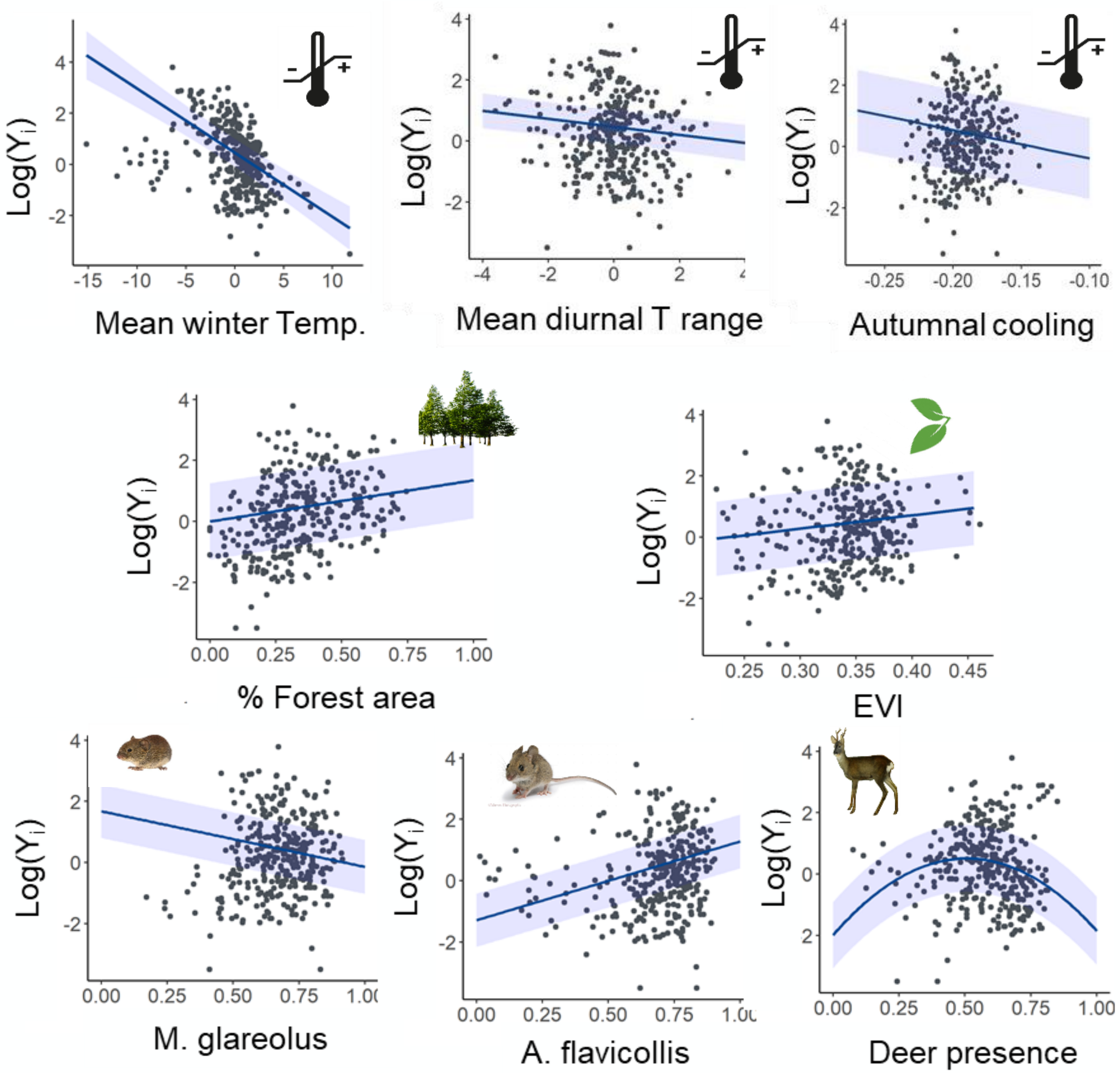




5. Multi-variable statistical analysis

Best parsimonious model





In conclusion..

- High **heterogeneity** both in study design and covariate types in published literature. Spatial models (Species distribution, TBE risk assessment) based on Remote Sensing became more frequent in recent years.

- Importance of **temperature**, **vegetation** and **hosts presence** in explaining the variation of TBE incidence across Europe.

- Importance of high-resolution **satellite data** in large-scale risk mapping.

- We defined **critical factors**, their main data sources and potential alternative variables, and assessed their interrelation with TBE incidence at a **continental scale**. This study could therefore inform future modeling efforts aimed at assessing disease risk.

Acknowledgments

FONDAZIONE EDMUND MACH

FEM Eco-Health group

H2020

MOOD — MOnitoring Outbreaks for Disease surveillance in a data science context

ISTITUTO SUPERIORE DI SANITÀ

E·R·G·O Environmental Research Group Oxford

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Thank you for your attention!

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