Disentangling the ecological conditions favoring West Nile virus hazard in the Old World

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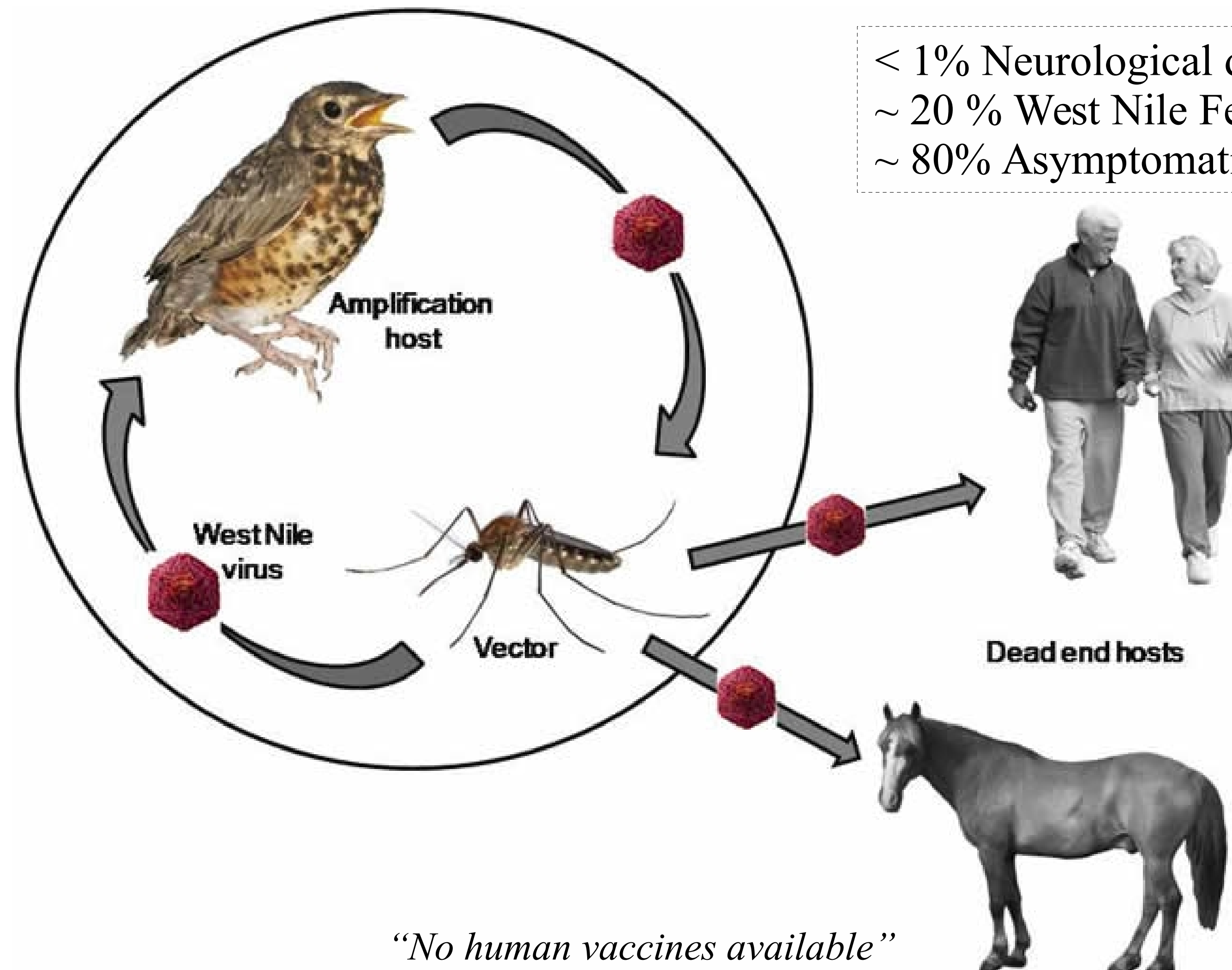
Introduction: WNV Biological Cycle

"By far, the most widely distributed arbovirus, isolated in all Continents apart from Antarctica"

"Emergence and spread of new lineages, and increased pathogenicity, is the cause of escalating public health concern"

< 1% Neurological disease
~ 20 % West Nile Fever
~ 80% Asymptomatic

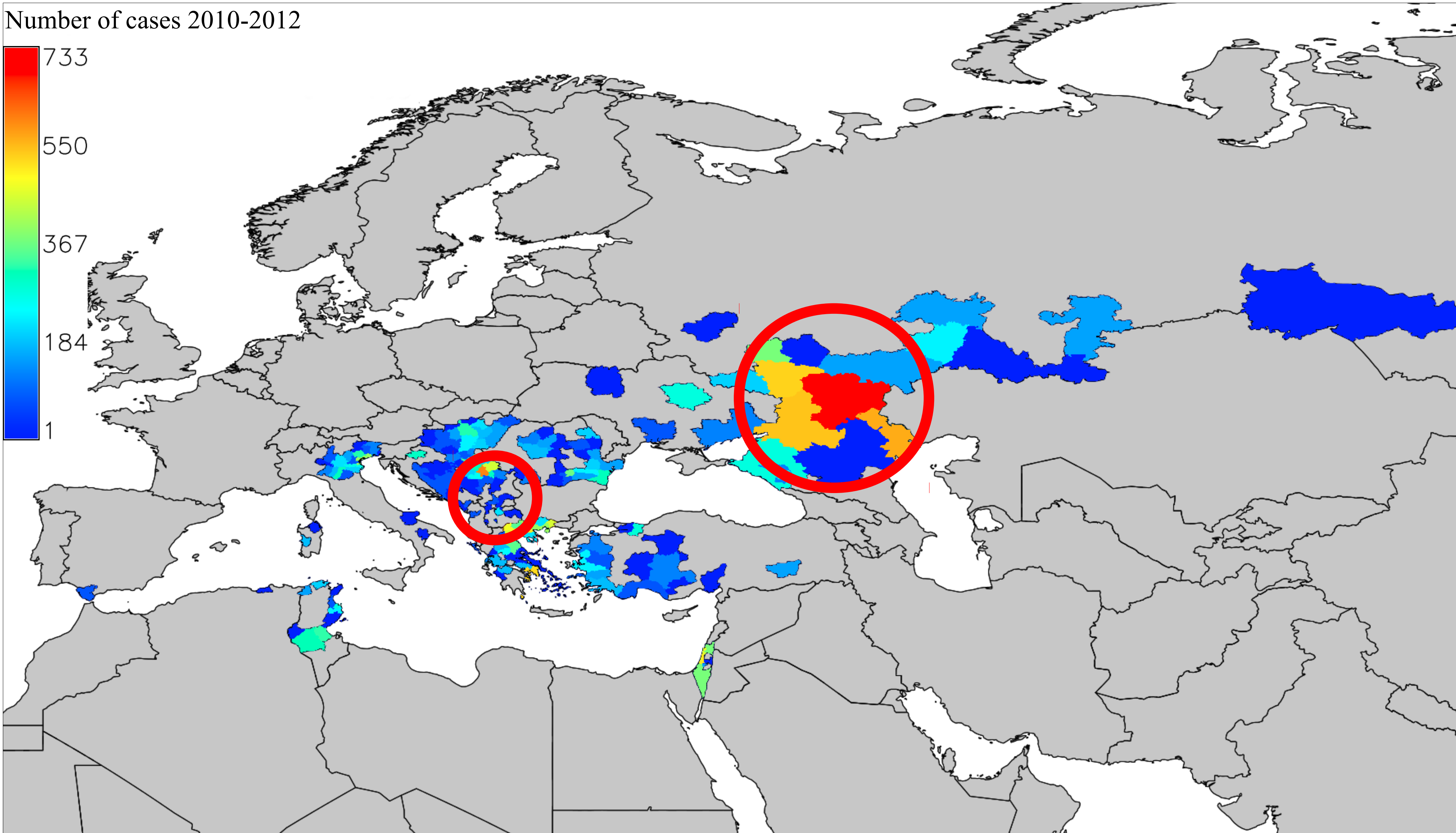


"No human vaccines available"

"Prevention currently depends on organized, sustained vector control campaigns and risk communication"

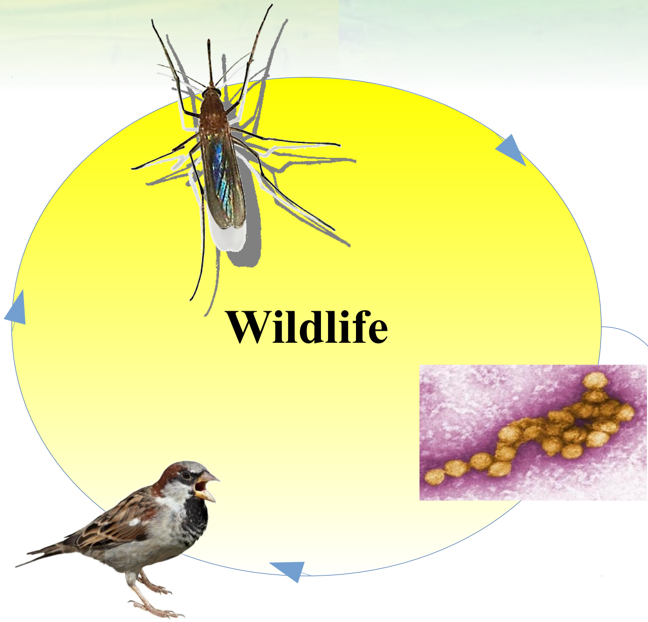
Introduction: WNV human cases distribution in the Old World

2,248 WNF human cases in Europe and neighbourhood countries from 2010 to 2012 reported by ECDC from 146 areas defined at the NUTS3/GAUL1 level.



Introduction: Aims

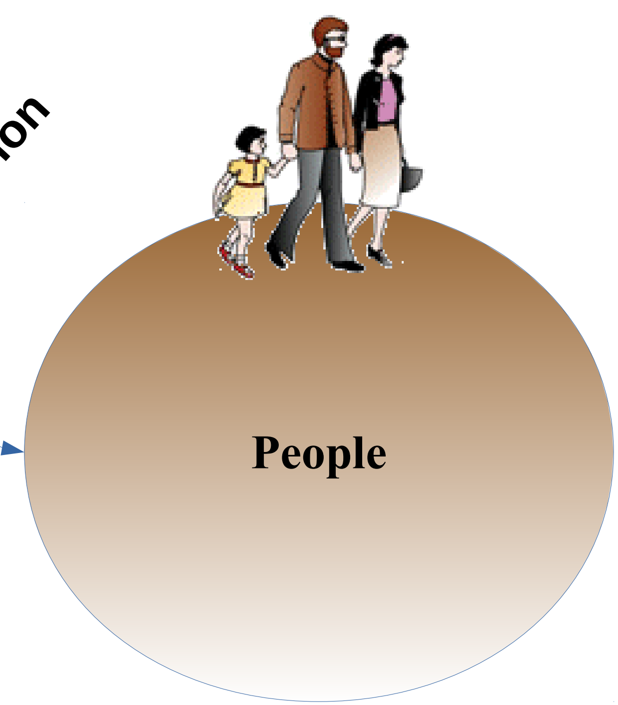
Modelling WNF incidence in the Old World to identify the ***environmental*** *conditions associated with occurrence in* ***humans.***



?

Permissive Environmental conditions

Transmission

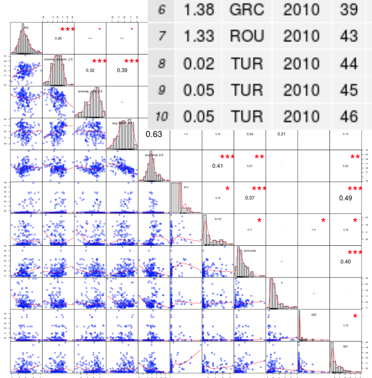


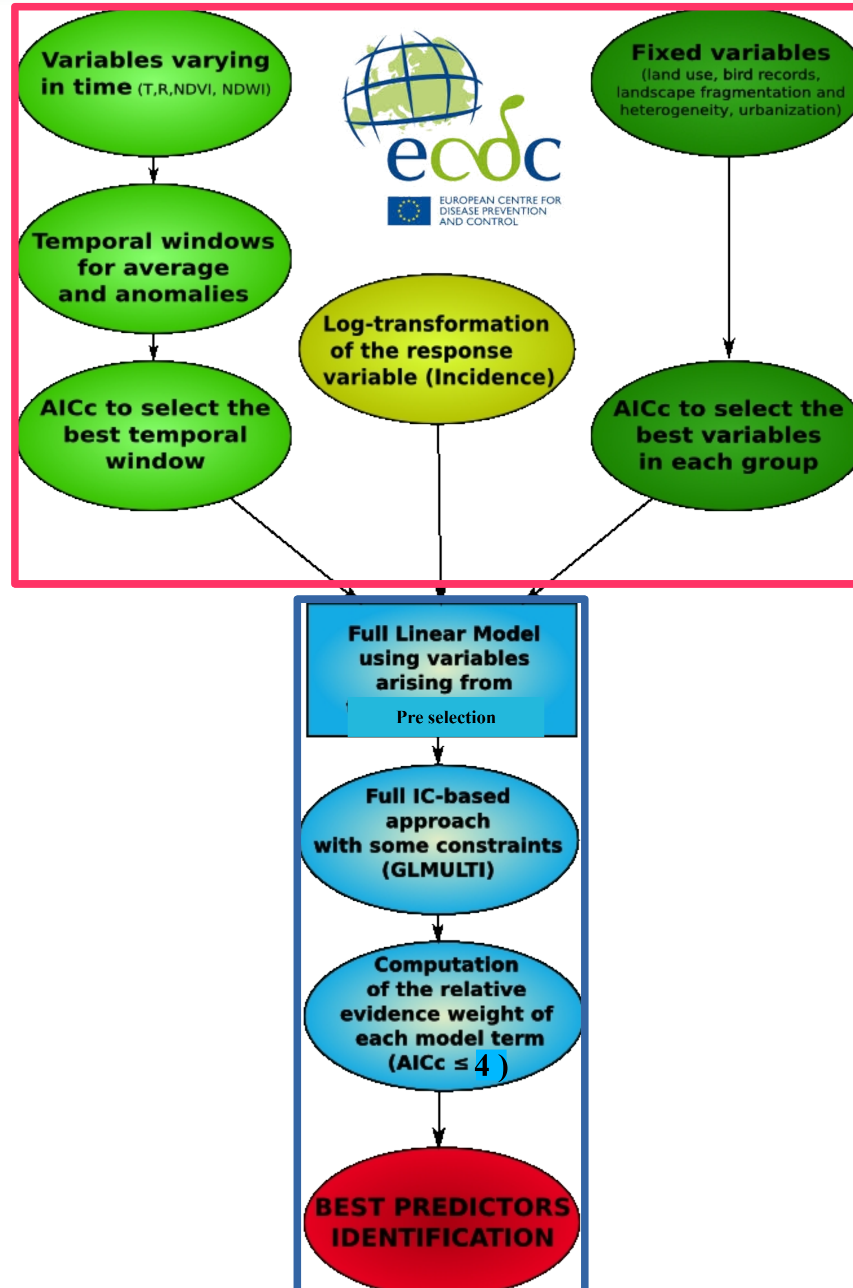
By identifying ***key environmental drivers*** *of WNF, we aim to* ***lay the foundations*** *for the development of statistical models able to* ***predict*** *WNF risk at* ***a continental scale****.*

Methods: Workflow

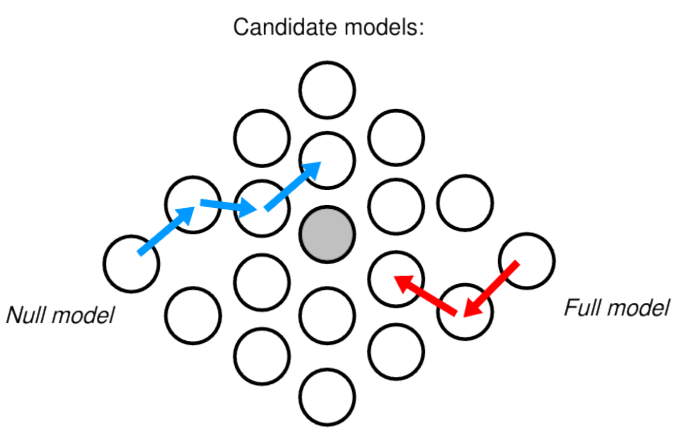
Data preparation and screening

	INC	NA	YEAR	ID	COUNTRY	REGION	POP	TOT	anomaly_dayprec_2.5	tot_dayprec_2.5
1	1.45	GRC	2010	11	Italy	Achaea	345380	5	-12.926377	7.58
2	0.05	TUR	2010	13	Italy	Adana	2026319	1	-10.668877	18.82
3	0.45	RUS	2010	14	Italy	Adygey	440400	2	-3.477185	44.30
4	0.14	TUR	2010	34	Greece	Afyon	697365	1	-16.671523	0.44
5	0.46	GRC	2010	38	Greece	Aitolia	217497	1	-2.168524	25.45
6	1.38	GRC	2010	39	Greece	Aitolia	217497	3	5.678110	36.45
7	1.33	ROU	2010	43	Greece	Alba	374535	5	9.638053	58.36
8	0.02	TUR	2010	44	Greece	Ankara	4548939	1	-13.174538	1.35
9	0.05	TUR	2010	45	Greece	Antalya	1859275	1	-6.569867	25.99
10	0.05	TUR	2010	46	Greece	Antalya	1859275	1	3.834504	42.65





Model selection and Multimodel Inference



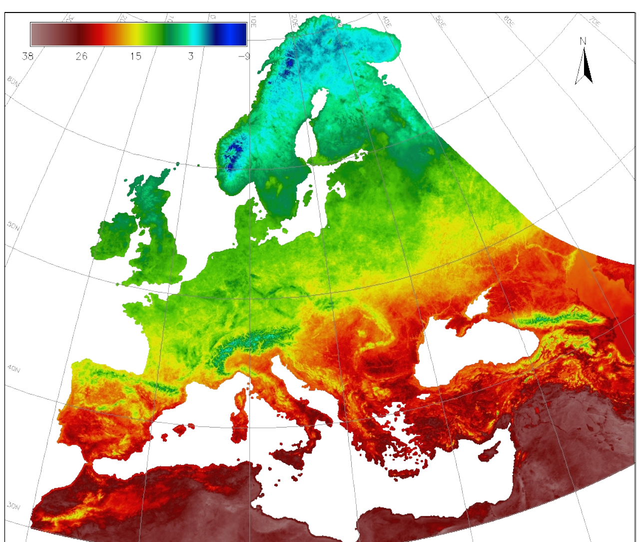
Methods: Data preparation and pre-selection of predictor variables

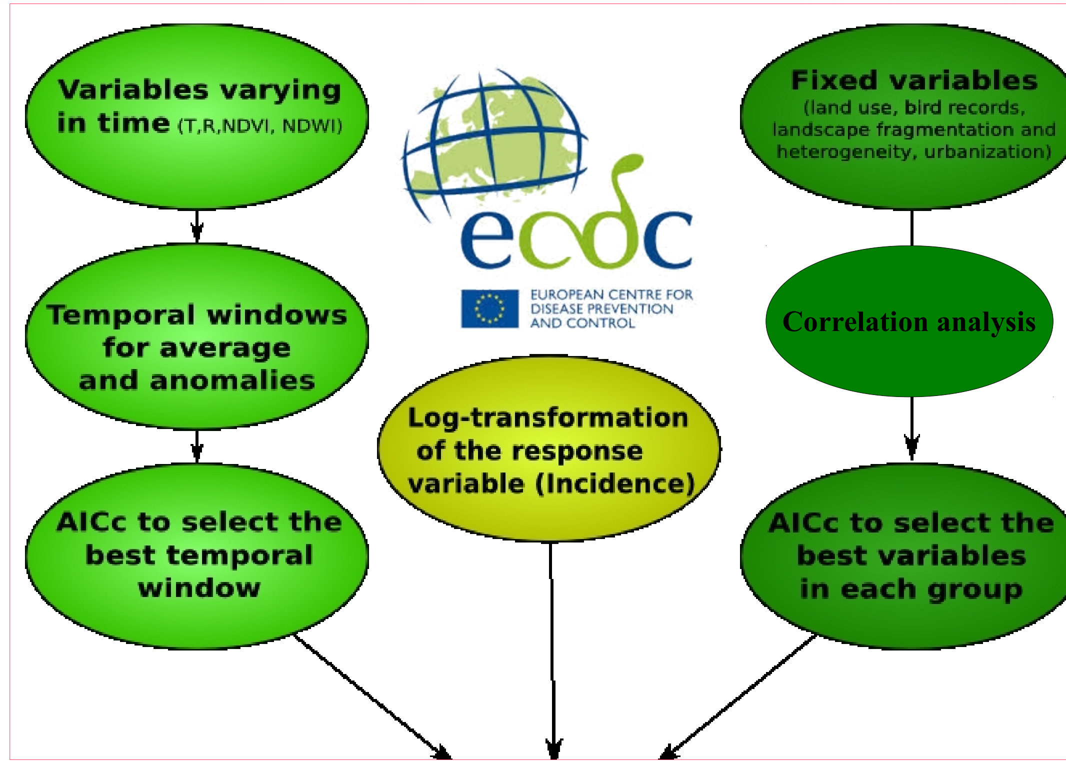
Response variable:

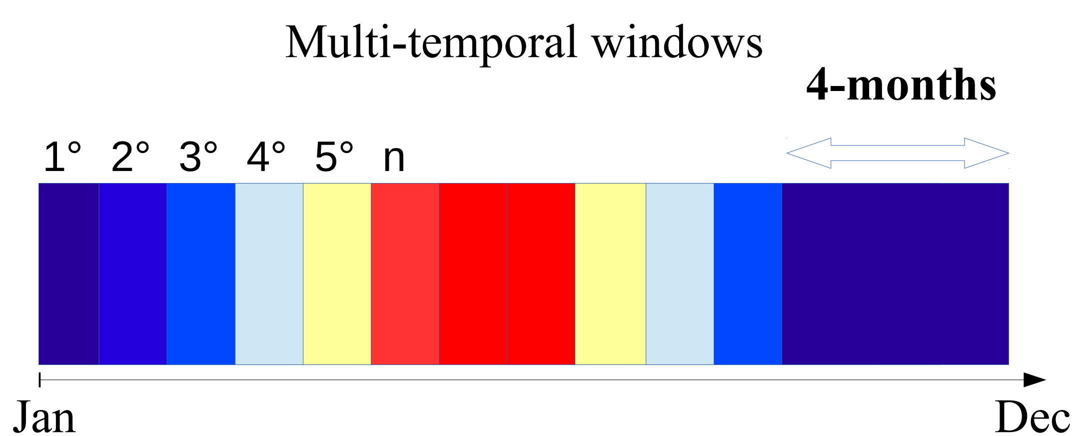
- WNF Annual incidence (Number of cases / Population) * 100,000; NUTS3)

Predictor variables:

- <u>Temperature (multitemporal windows)</u>
- <u>Precipitation (multitemporal windows)</u>
- <u>Vegetation Index (multitemporal windows)</u>
- <u>Water Index (multitemporal windows)</u>
- Land use (Glob Cover)
- Human footprint (Anthromes)
- Human population (VIIRS)
- Bird abundance (GBIF)
- Protected areas (UNEP)
- Water Body (OpenStreetMap)
- Landscape evenness index



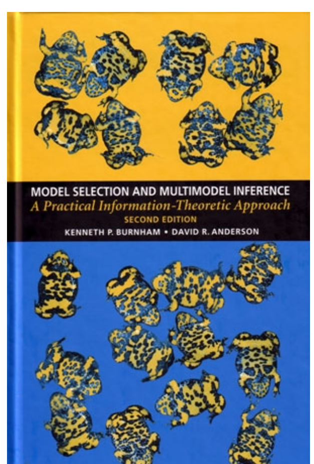




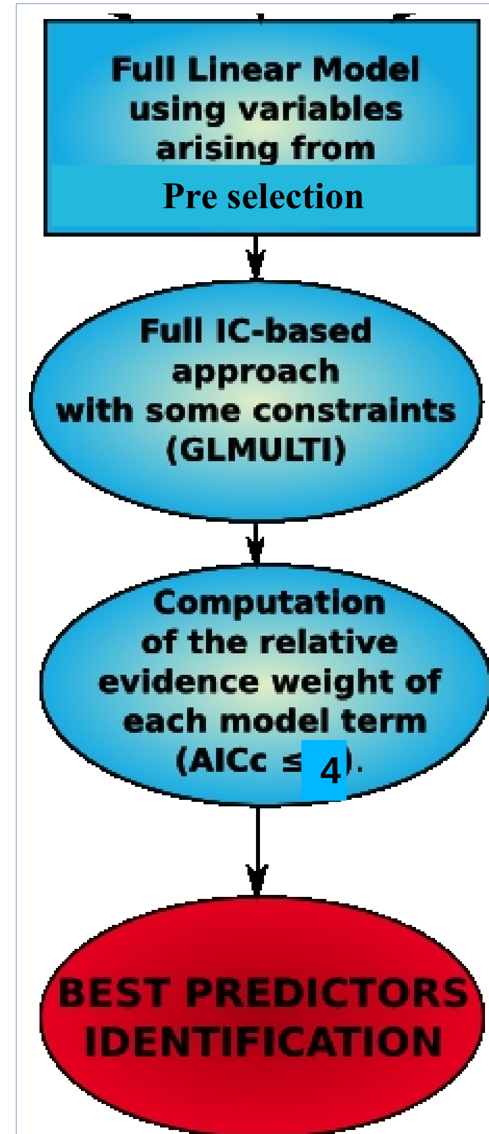
WNF Annual incidence (NUTS3) ~ Temporal window$_n$ = AICc value

Methods: Model selection and Multimodel Inference

- **Linear Mixed-effect Model** (LMM) to consider the clustering of incidence in districts and years.
- Running LMMs with all possible **combinations** of predictors.
- **Ranking** LMMs using AICc (**Multi model selection**).
- Selection of all LMMs in **ΔAICc < 4** (Statistically very similar; model-selection uncertainty).
- **Classify** the predictors using the "Relative Importance Weight".
- **Averaged predictor coefficients** and confidence intervals using all the models in the best set (**Multi model inference**).



Model selection and Multimodel Inference
(Burnham and Anderson 2002)



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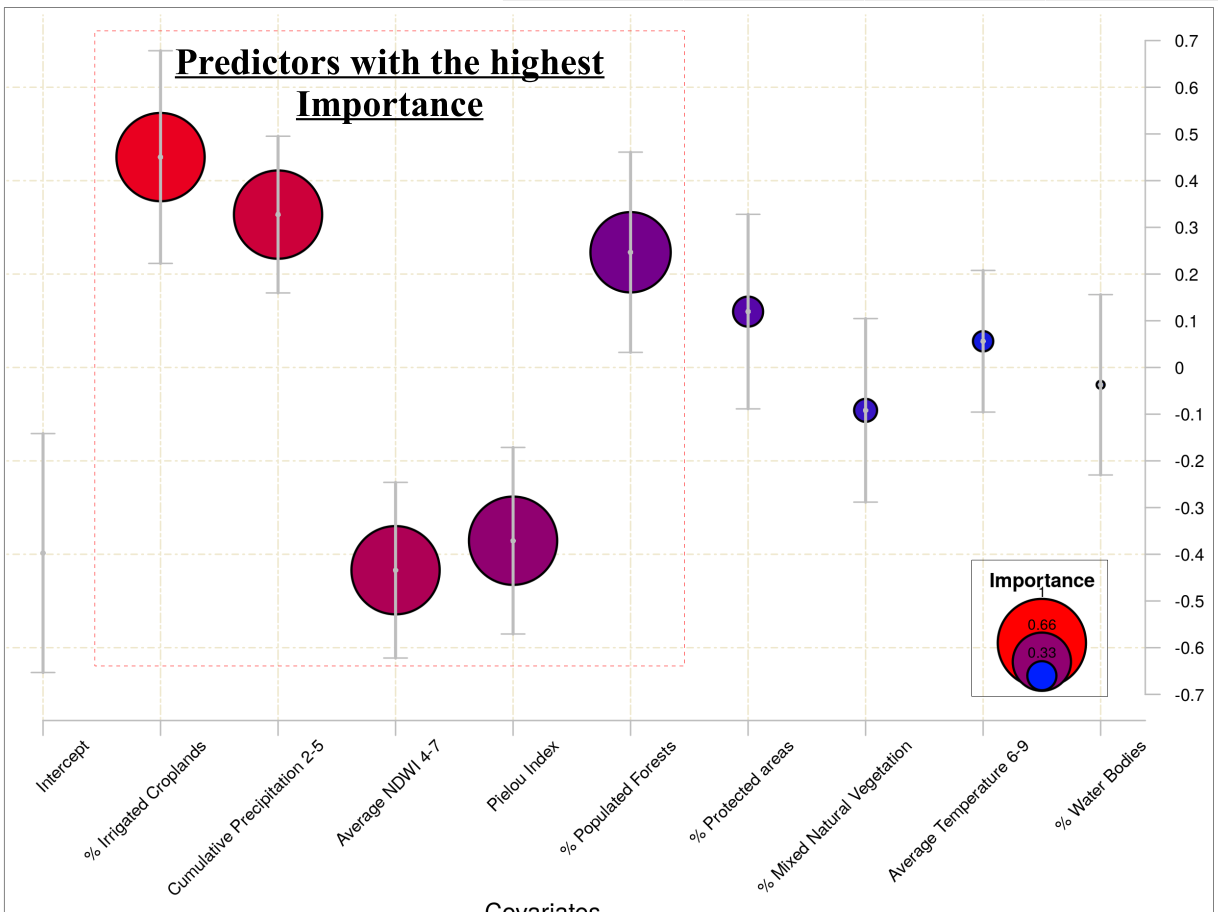
Results: Best Model, Best models set, Best predictors set

lmer(log(Incidence) ~ Anomaly Precipitation 2-5 + Average NDWI 4-7 + Pielou + % Populated forest + % Cropland + (1|YEAR) + (1|REGION))

Model	Params	AICc	Δ_i	$L(g_i \mid x)$	w_i	ER
1	**9**	**617.42**	**0.00**	**1.00**	**0.22**	**1.8**
2	10	618.60	1.16	0.56	0.12	
3	10	618.86	1.44	0.49	0.11	
13	…	…	4	…	…	



- ~ **100** initial potential predictors.
- **14 predictors** in the LMM.
- Relatively **little evidence** for the best model.
- **13 models** in the best model set.
- **9 predictors** in the best models set:

1. <u>% cover of irrigated croplands +</u>
2. <u>Precipitation in late winter/early spring +</u>
3. <u>% cover of populated forests +</u>
4. <u>Landscape evenness index **-**</u>
5. <u>Summer average water index **-**</u>
6. % cover of protected areas +
7. Summer average temperature +
8. % cover of water bodies -
9. % cover of mixed natural vegetation -

- Predicted vs. Observed $\mathbf{R^2 = 0.32}$

Discussion

+ Positive relationship
– Negative Relationship

- **General discussion**
  - **High importance** of both **climate and land use** variables.
  - Other variables less relevant (e.g. bird abundance, NDVI, human population density).

- **Climatic conditions**

+ **Late winter-early spring precipitation anomalies**. Suitable ecological niches (accumulation of high amount of ground water).

+ **Summer temperature**. High temperature speeds up mosquito population dynamics and virus replication.

– **Summer NDWI**. Summer drought condition may create localized habitats (small remnant ponds?) where mosquitoes and birds may gather together.

- **Land use and landscape structure**

+ **Populated forests**. Environmental gradients might enhance virus spill over from sylvatic cycle (exposure to infected mosquitoes).

+ **Irrigated croplands** and **water bodies** may favour the concomitant presence of mosquitoes, birds and humans in the same place.

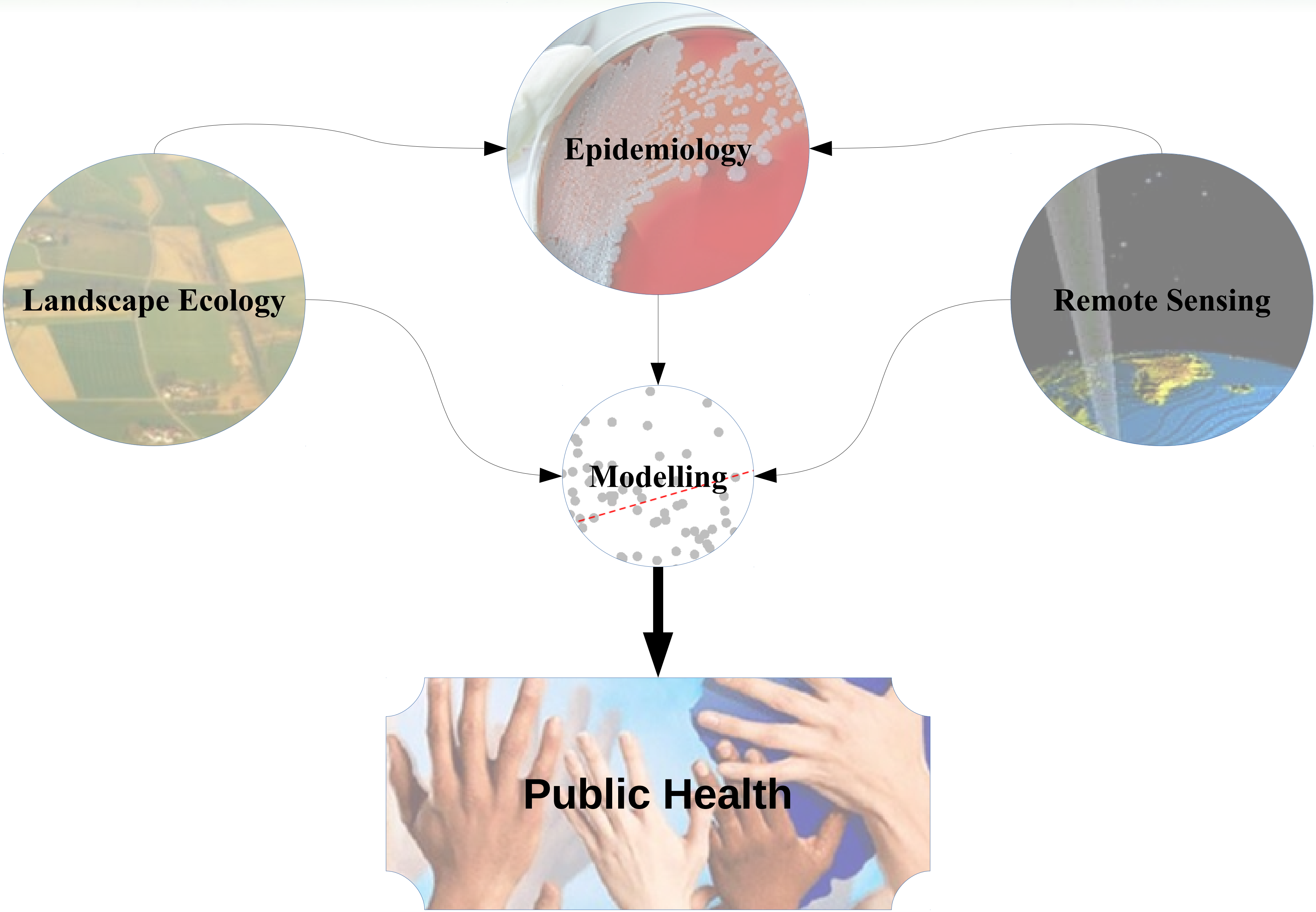
– Pielou index – **Landscape Evenness has a negative effect**. The more even is the landscape the lower WNV incidence (i.e., populated forest low even).

Conclusions and Future Research

- **First attempt** to model WNF incidence at continental scale in Europe.
- **Both climate** and **land use** should be considered as predictors for WNV hazard at **large spatial scale**.
- Land uses that allow the **co-occurrence of vector and hosts** are key for the virus circulation.

- Large-scale study can be better understood if **fine-scale data** are available and the same hypotheses tested on them.
- Inclusion of other variables such as **birds migration routes** and **socio-economical indicators**.
- **Bayesian Inference** could improve the model performance allowing the inclusion of prior knowledge.

Overview


Epidemiology
Landscape Ecology
Remote Sensing
Modelling
Public Health

Thanks!

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Questions? Suggestions? Comments?