Remote Sensing of Biodiversity Workshop – Grenoble, November 24th - 25th 2014
GdR MAGIS – IEEE GRSS – ZA Alpes

Modeling bird species diversity at broad scale from satellite imagery

Finding the best spatial representation of habitats

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1. Context of the study

REVIEW

doi:10.1038/nature11148

Biodiversity loss and its impact on humanity

Bradley J. Cardinale[1], J. Emmett Duffy[2], Andrew Gonzalez[3], David U. Hooper[4], Charles Perrings[5], Patrick Venail[1], Anita Narwani[1], Georgina M. Mace[6], David Tilman[7], David A. Wardle[8], Ann P. Kinzig[5], Gretchen C. Daily[9], Michel Loreau[10], James B. Grace[11], Anne Larigauderie[12], Diane S. Srivastava[13] & Shahid Naeem[14]

Nature 486, 59–67 (June 7, 2012)

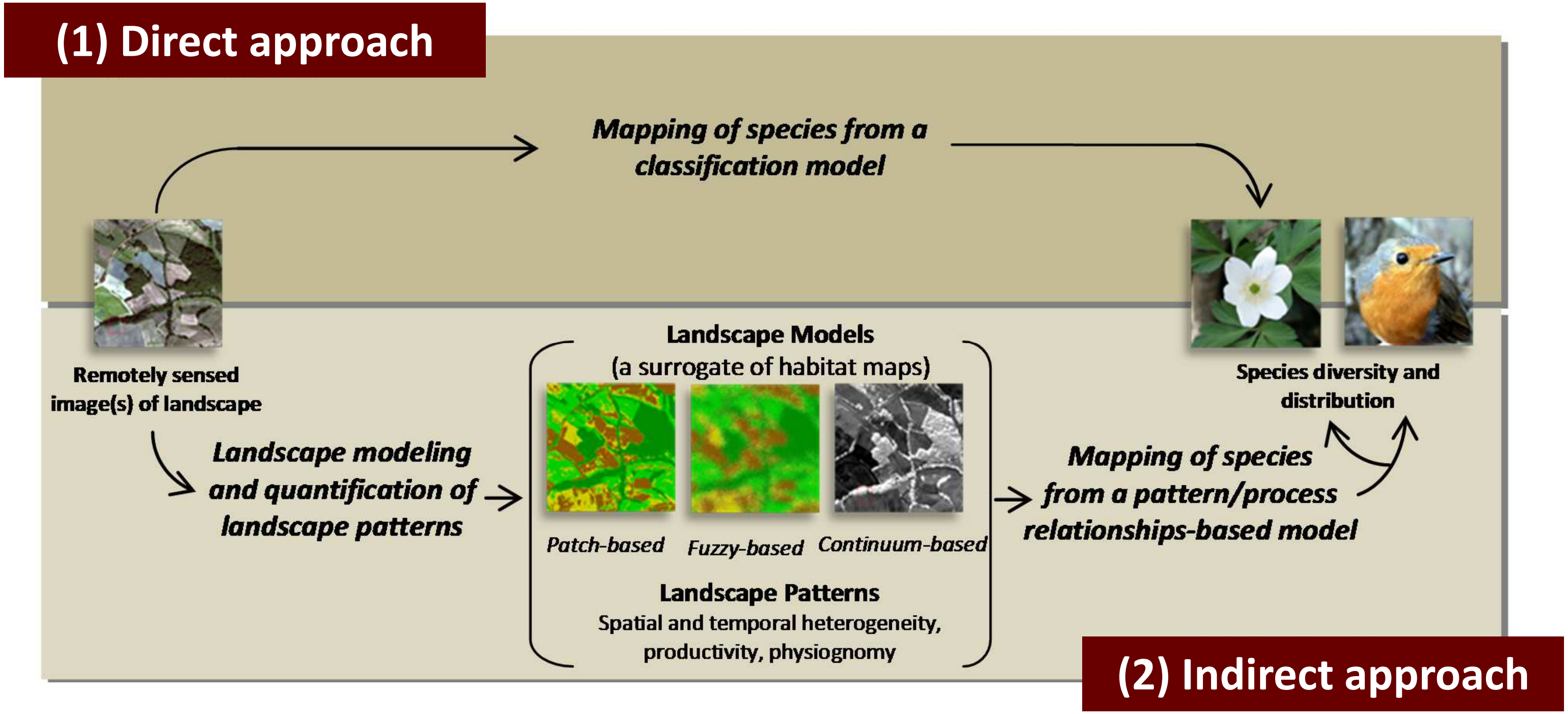
Where are the species and areas of primary importance?

How to assess and monitor biodiversity?

1. Context of the study

Remote sensing for mapping or predicting biodiversity

(Nagendra 2001, Duro et al. 2007, Gillespie et al. 2008)



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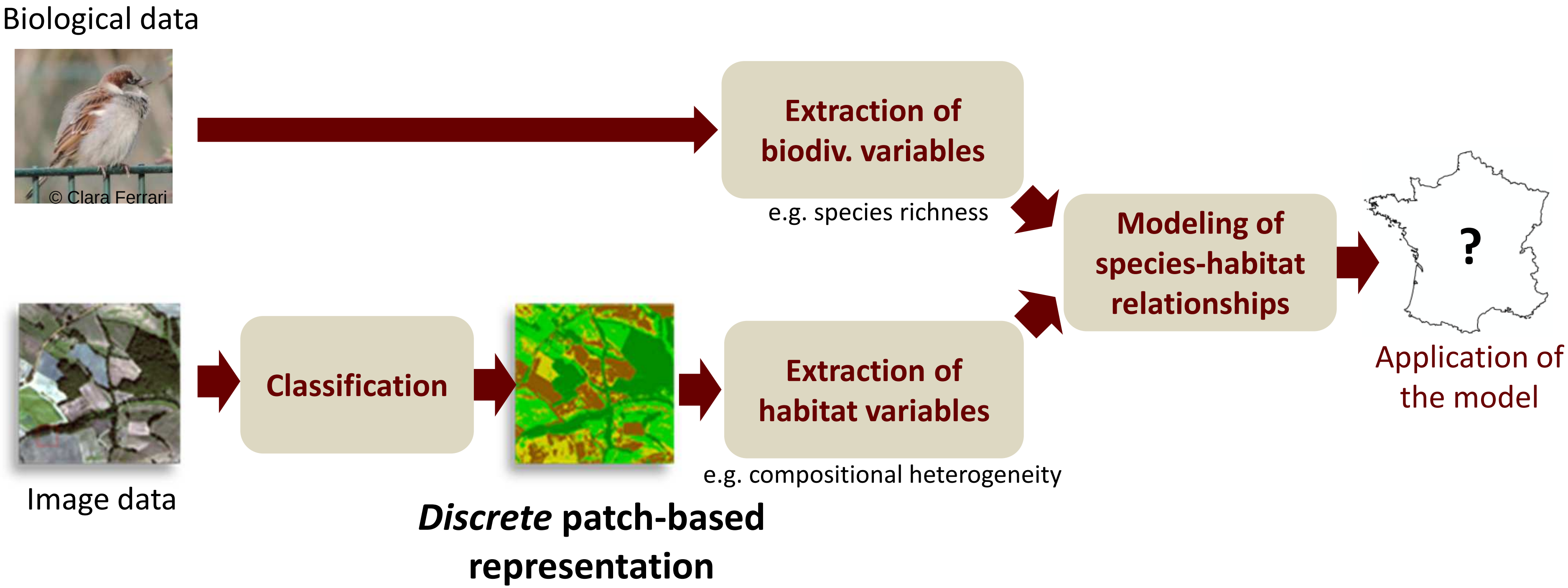
Predominant approach (e.g. Gootschalk et al. 2005):

Land-cover map as a proxy of species diversity



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Biological data

Extraction of biodiv. variables

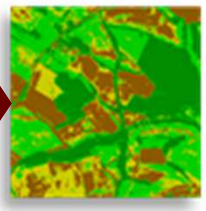
e.g. species richness

Modeling of species-habitat relationships

Application of the model

Image data

Classification



***Discrete* patch-based representation**

Extraction of habitat variables

e.g. compositional heterogeneity

Limits:

Human-defined boundaries of classes

Misclassification errors

Time-consuming

1. Context of the study

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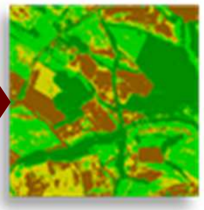

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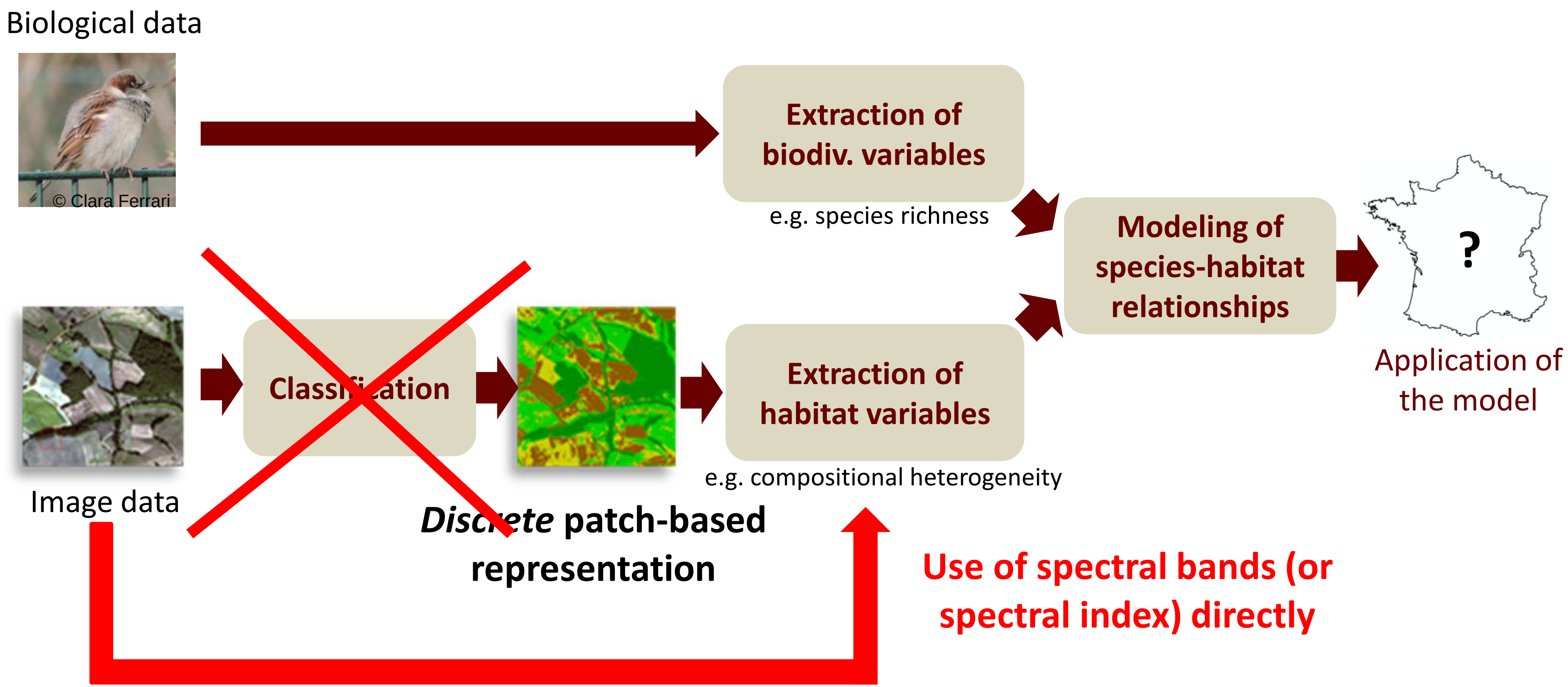

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Image data

***Continuous* representation**

Extraction of biodiv. variables

e.g. species richness

Extraction of spectral variables

e.g. NDVI heterogeneity

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***Continuous* representation**

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Interests:

Less anthropocentric
No classification errors
More operational for large areas

2. Aims of the study

- **Exploring** the potential of **unclassified imagery** to predict bird species richness in France
- **Comparing** the performance of bird-habitat models based on **continuous and discrete representation** of habitats

2. Aims of the study

Why birds?

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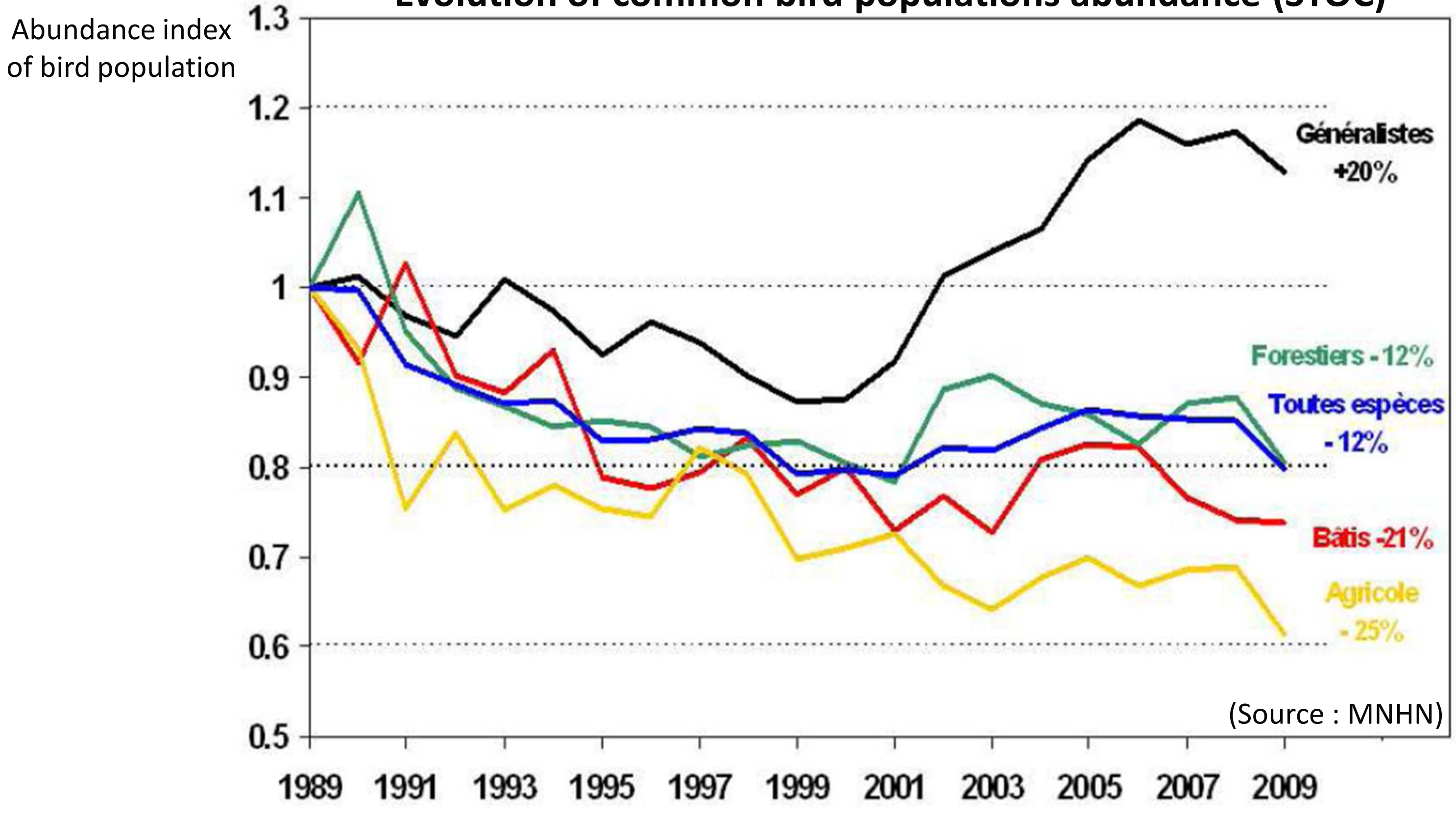
Why birds?

Evolution of common bird populations abundance (STOC)



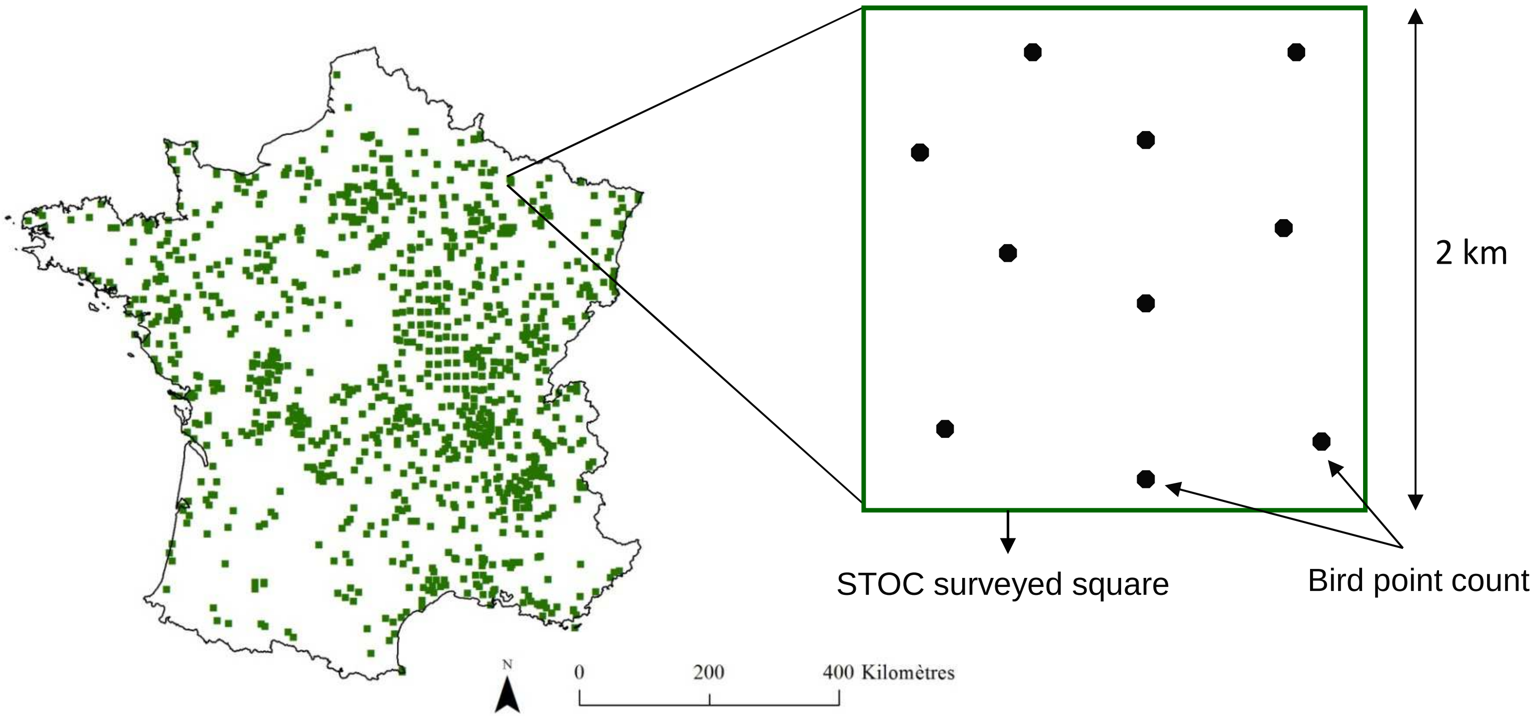
- Well-known taxon with large dataset available at national scale
- Sensitive to global change (Jiguet *et al.*, 2007; Julliard *et al.*, 2004)

3. Material

Bird data:

- **French Breeding Bird Survey** (STOC program - MNHN)

  - Square of 2x2 km including 10 bird point counts visited twice
  - 1094 squares recorded in 2010 throughout the France



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  - Square of 2x2 km including 10 bird point counts visited twice
  - 1094 squares recorded in 2010 throughout the France

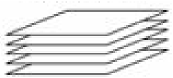
Response variables (for each square) :

- **Taxonomic diversity (sp. richness)** : woodland species, farmland species, urban species, generalist species, sum of the four groups
- **Functional diversity**: Community Trophic Index (CTI), Community Specialization Index (CSI) (Julliard et al. 2006 ; Devictor *et al*., 2008)

3. Material

Remotely-sensed data:

- **(1) MODIS image time-series**
  - **Vegetation index (NDVI & EVI)**



    - 16-day composit product at 250-meter (MOD13Q1)

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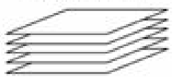
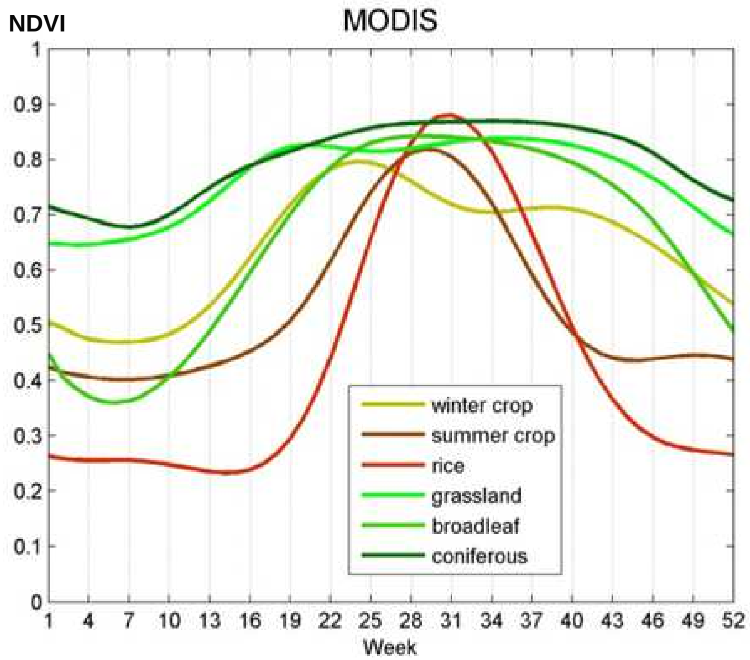


    - 16-day composit product at 250-meter (MOD13Q1)

Provide information about the vegetation state and functioning



Source : Atzberger *et al.*, 2014

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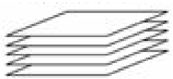

  - **Land Surface Temperature (LST Day)**
    - 8-day composit product at 1km (MOD11A2)

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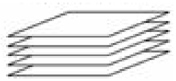

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Variations according to land cover type and
fractional vegetation cover as well as soil moisture

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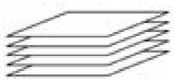

Explanatory variables based on two landscape representations:

3. Material

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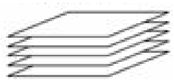

Explanatory variables based on two landscape representations:

(1) Continuous-based variables

Mean and *variance* of NDVI/LSTD index within the STOC squares of bird surveys

3. Material

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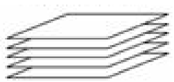

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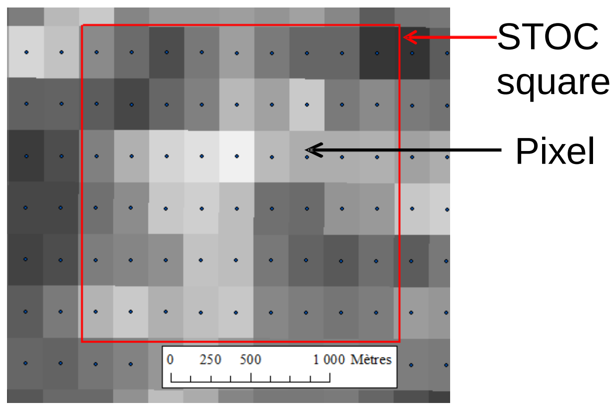

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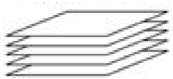

Explanatory variables based on two landscape representations:

(2) **Discrete-based** variables

% of functional classes within the STOC squares of bird surveys

3. Material

Remotely-sensed data:

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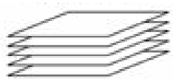
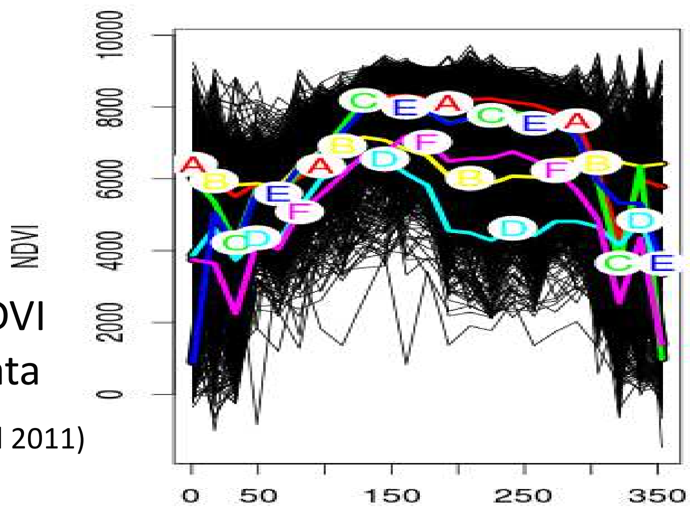


  - **Vegetation index (NDVI & EVI)**
  - **Land Surface Temperature (LST Day)**

Explanatory variables based on two landscape representations:

K-means on NDVI longitudinal data

(Genolini et Falissard 2011)



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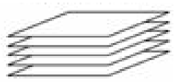

Explanatory variables based on two landscape representations:

(1) Continuous-based variables

Mean and *variance* of NDVI/LSTD index within the STOC squares of bird surveys

STATE

(2) **Discrete-based** variables

% of functional classes within the STOC squares of bird surveys

FUNCTIONING

3. Material

Remotely-sensed data:

- **(2) MODIS Vegetation Continuous Field (VCF) product**
  - % tree cover per pixel (250-meter)
  - Regression tree classification (Townshend et al. 2001)

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Explanatory variables based on
a continuous landscape representation:

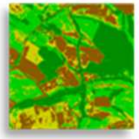
Mean and *variance* of VCF pixels
within the STOC squares of bird surveys

STATE

3. Material

Land cover data:

- **(3) CORINE Land Cover**



- The only land cover database covering all of France
- Dating from 2006, minimum mapping unit = 25ha

3. Material

Land cover data:

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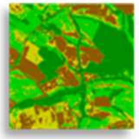

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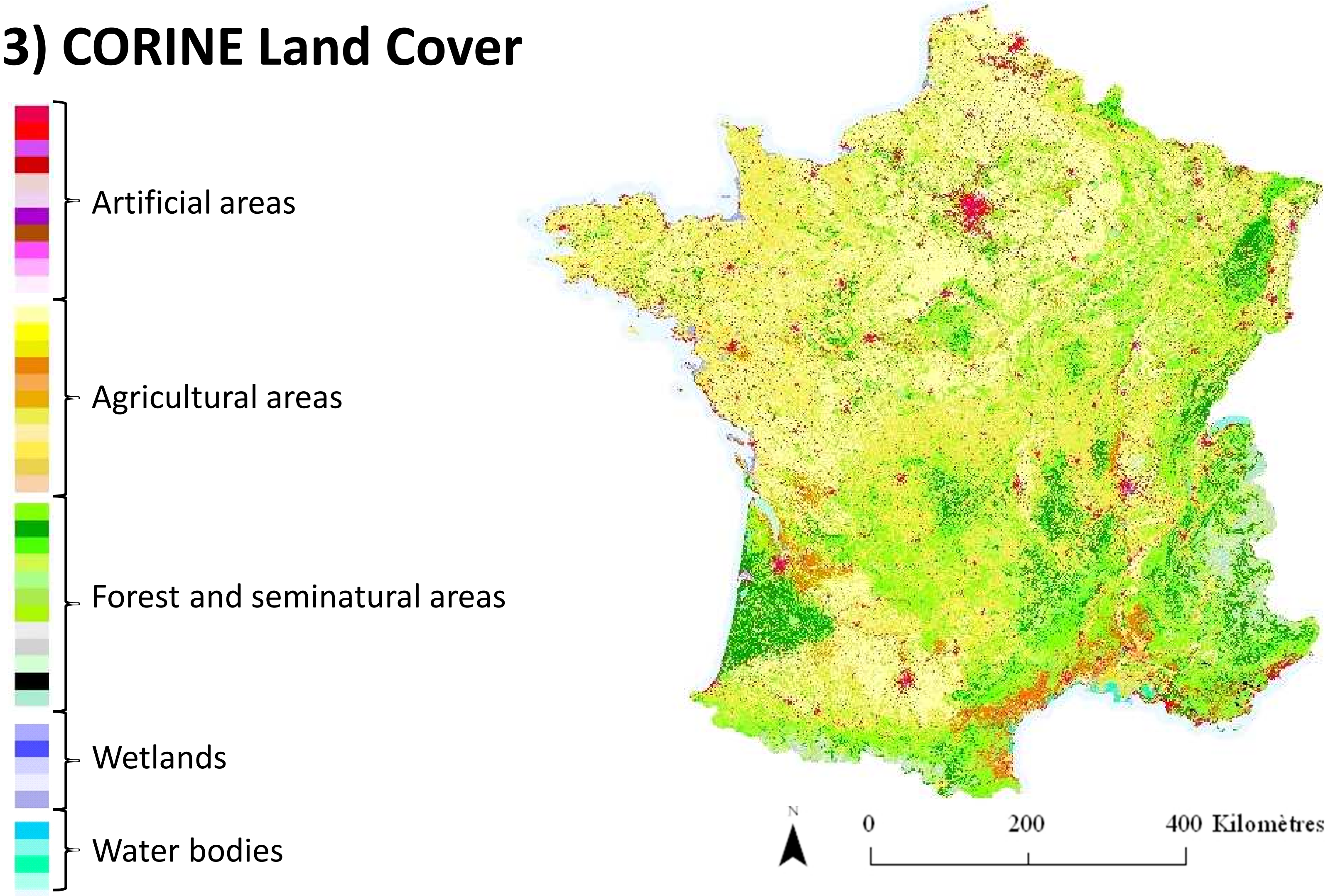
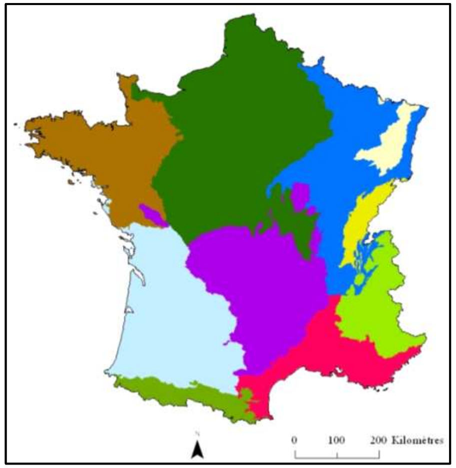


3. Material

Data for regionalization:

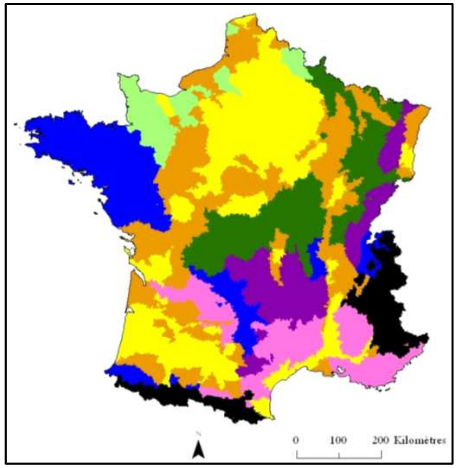
- **3 kinds of strata**

Eco-forestry strata



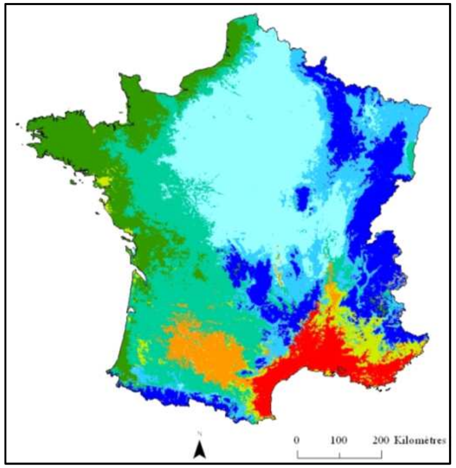
GRECO A : Grand Ouest cristallin et océanique
GRECO B : Centre Nord semi-océanique
GRECO C : Grand Est semi-continental
GRECO D : Vosges
GRECO E : Jura
GRECO F : Sud-ouest océanique
GRECO G : Massif Central
GRECO H : Alpes
GRECO I : Pyrénées
GRECO J : Méditerranée

Agricultural strata



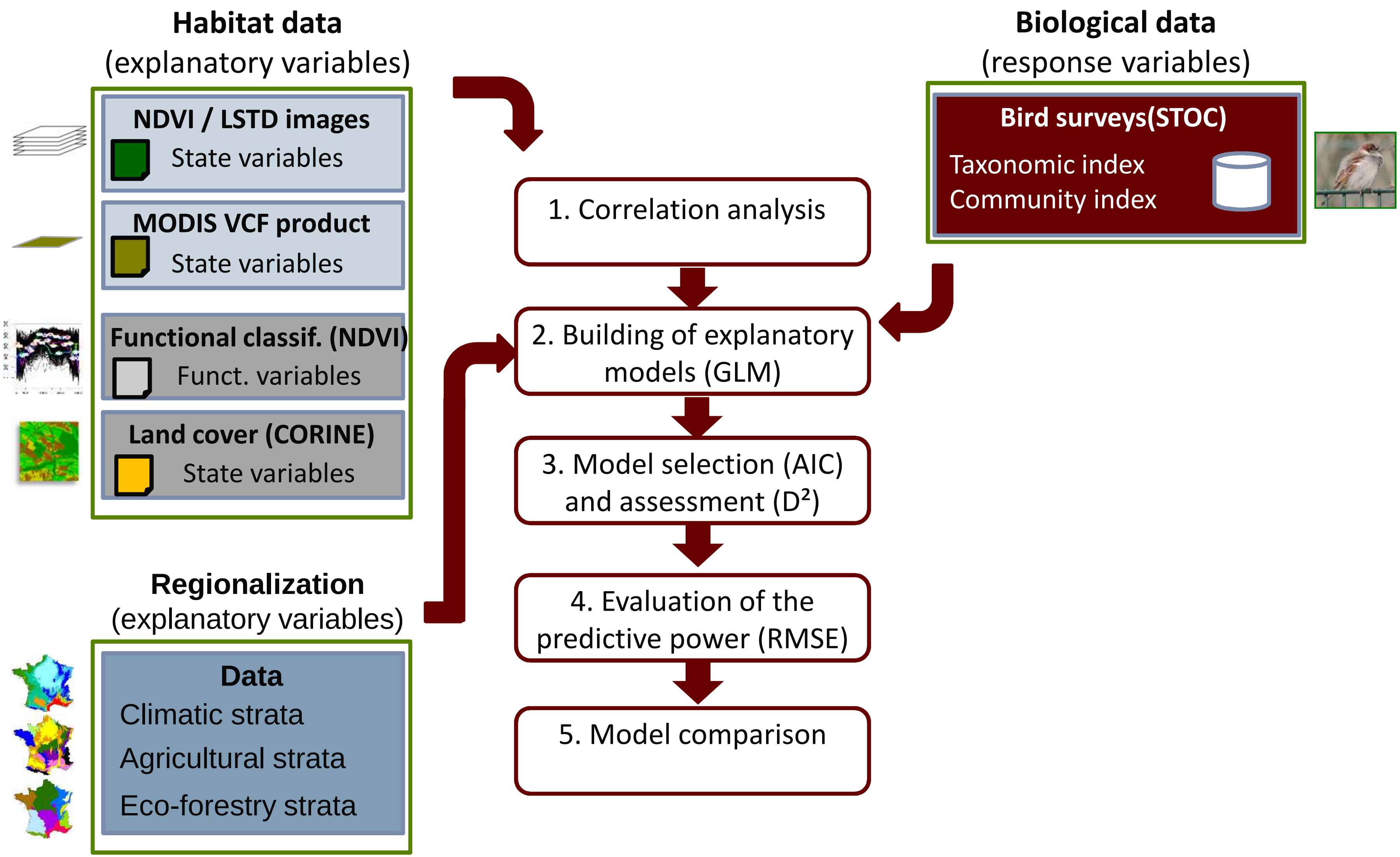
Zone 0 : Grandes cultures ou absence d'élevage
Zone 1 : Cultures et élevages
Zone 2 : Cultures fourragères (herbe et maïs)
Zone 3 : Zone herbagère du Nord-Ouest
Zone 4 : Zone herbagère du Centre et de l'Est
Zone 5 : Zones pastorales
Zone 6 : Montagnes humides
Zone 7 : Haute-Montagne

Climatic strata



Type 1 : les climats de montagne
Type 2 : le climat semi-continental et le climat des marges montagnardes
Type 3 :le climat océanique dégradé des plaines du Centre et du Nord
Type 4 : le climat océanique tempéré
Type 5 : le climat océanique franc
Type 6 : le climat méditerranéen altéré
Type 7 : le climat du bassin du Sud-Ouest
Type 8 : le climat méditerranéen franc
Hors interpolation

4. Methodological approach



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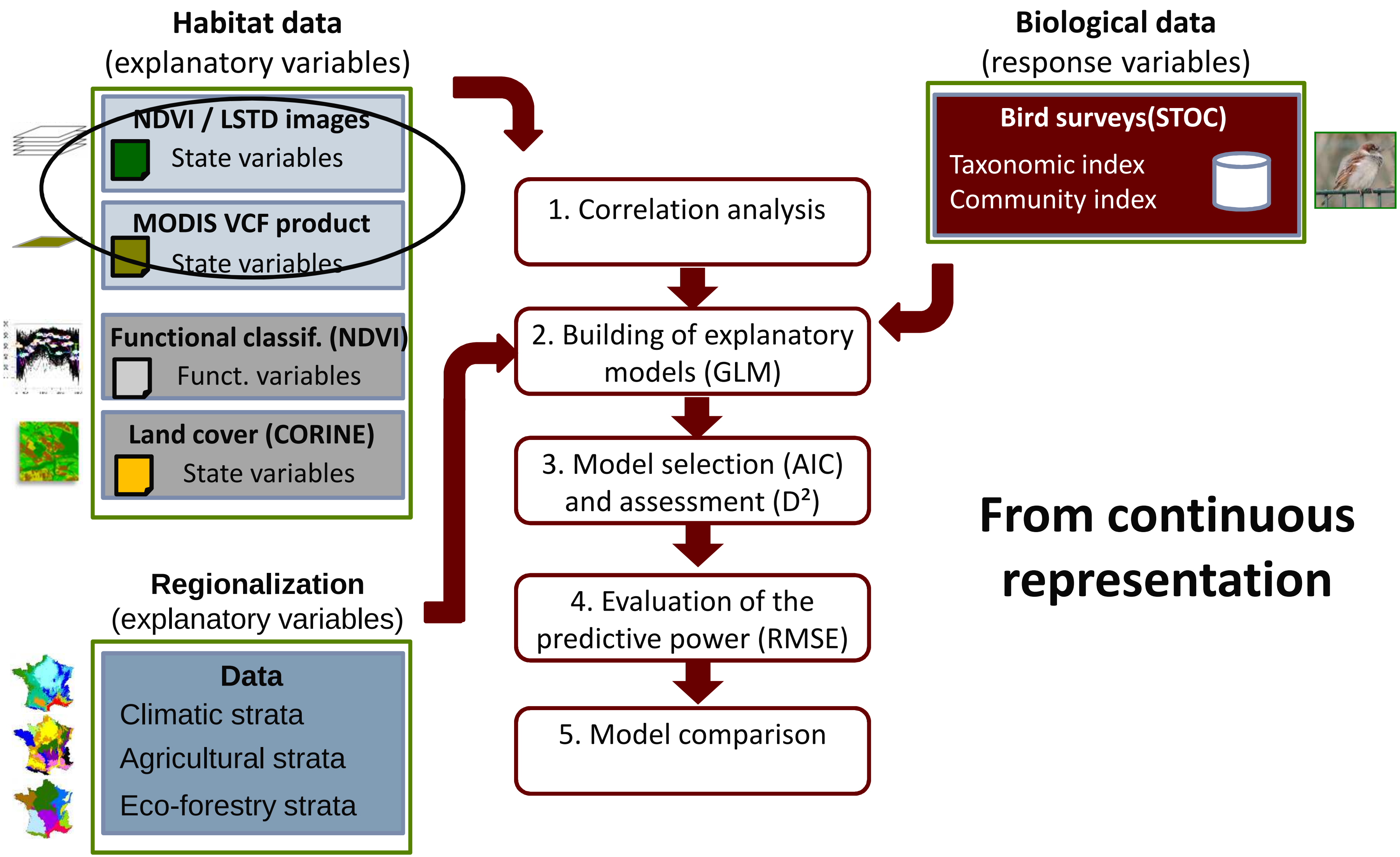

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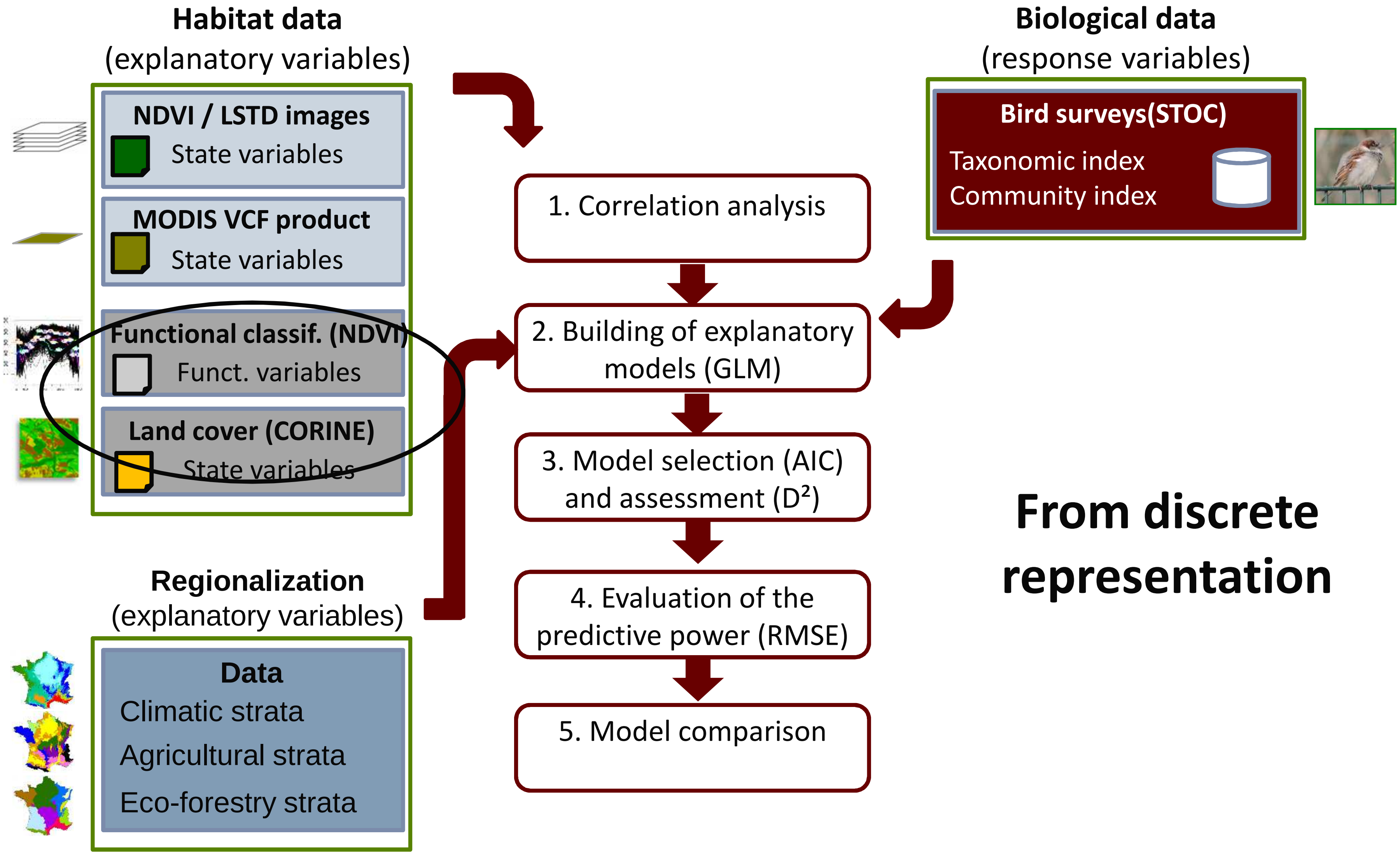

From discrete representation

5. Results

Bird species richness explained by *continuous representation*

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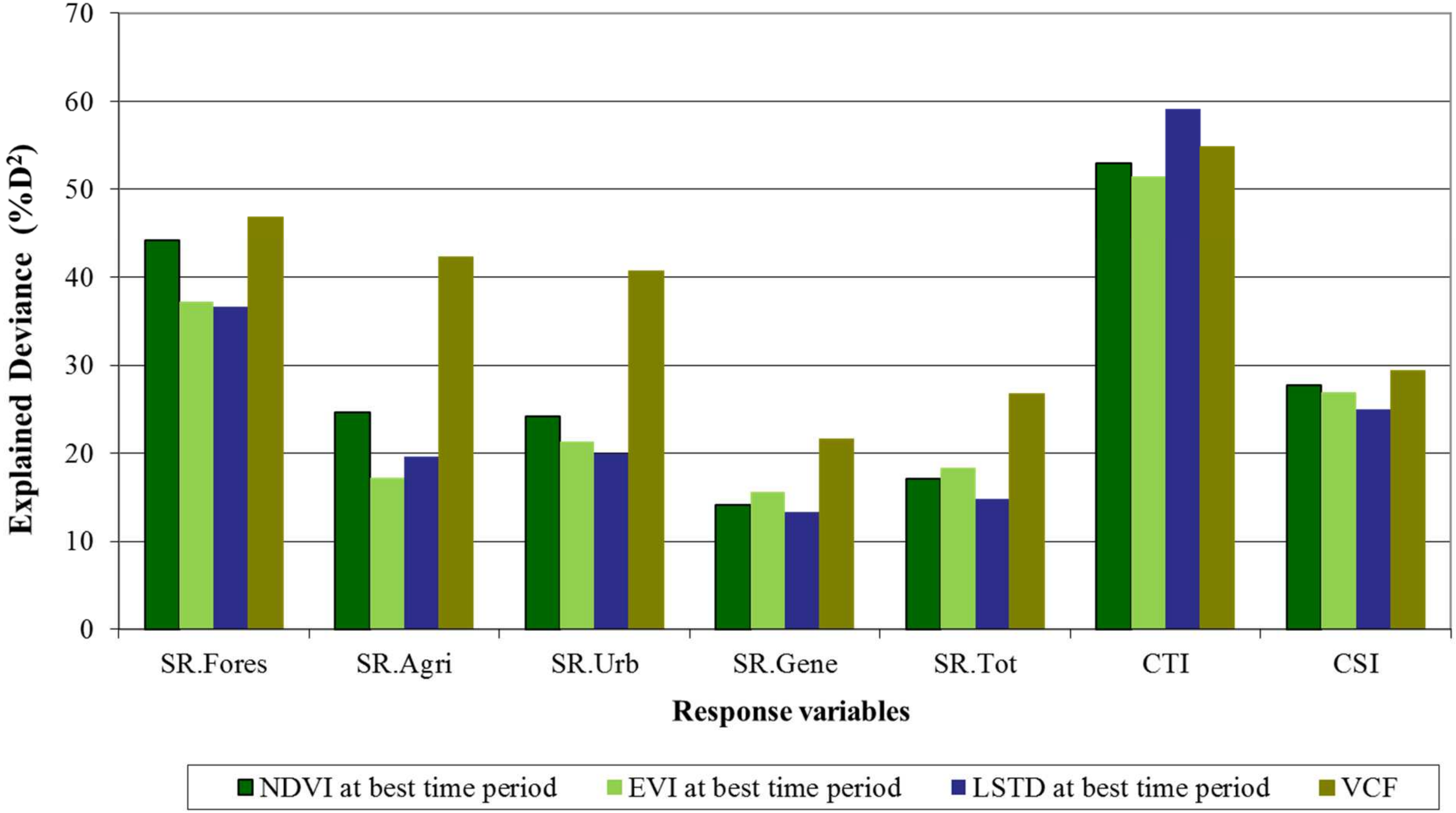
Bird species richness explained by *continuous representation*

NDVI & EVI, LSTD, VCF



5. Results

Bird species richness explained by *discrete representation*

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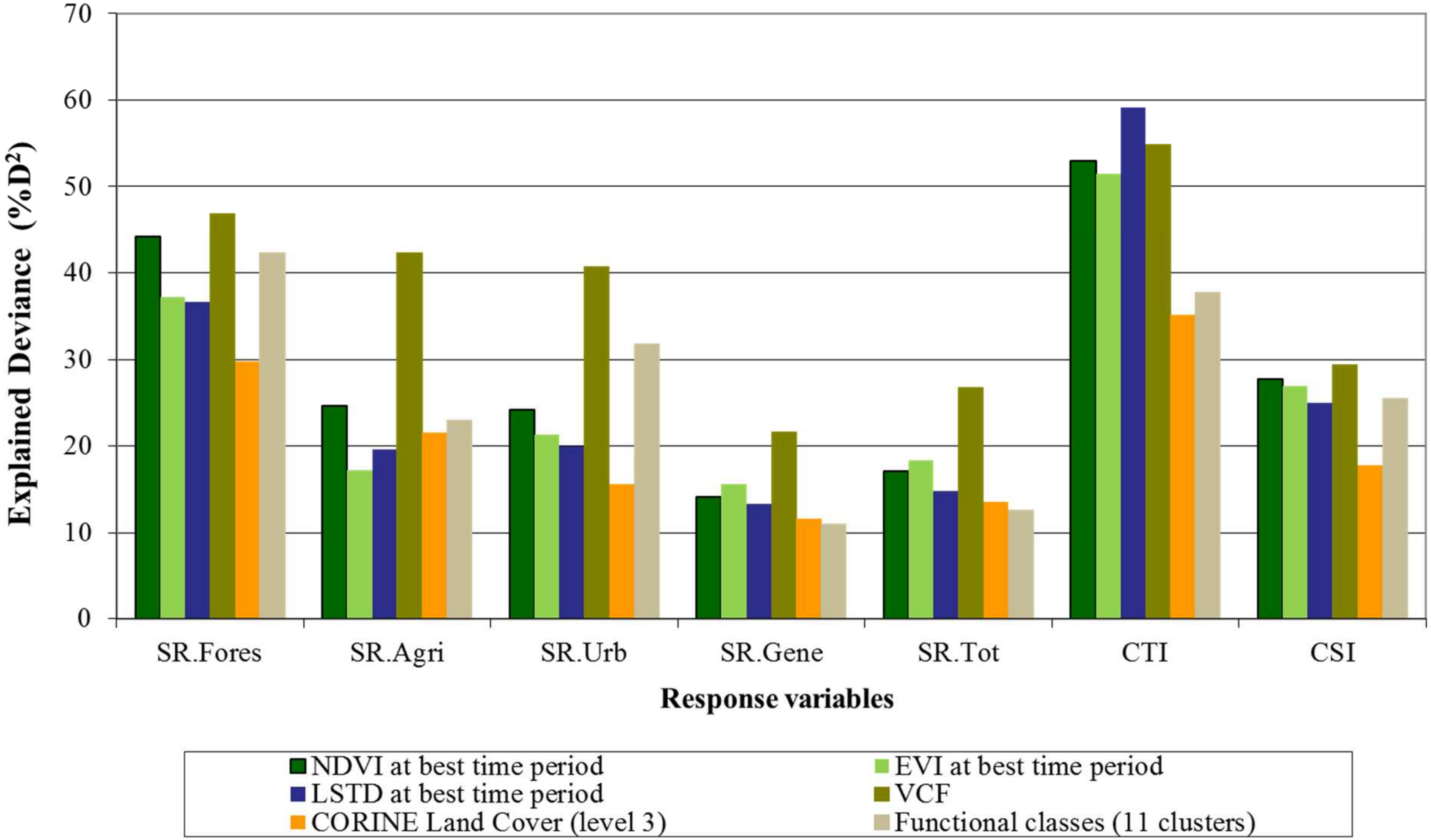
Bird species richness explained by *discrete representation*

CORINE, Functional classification

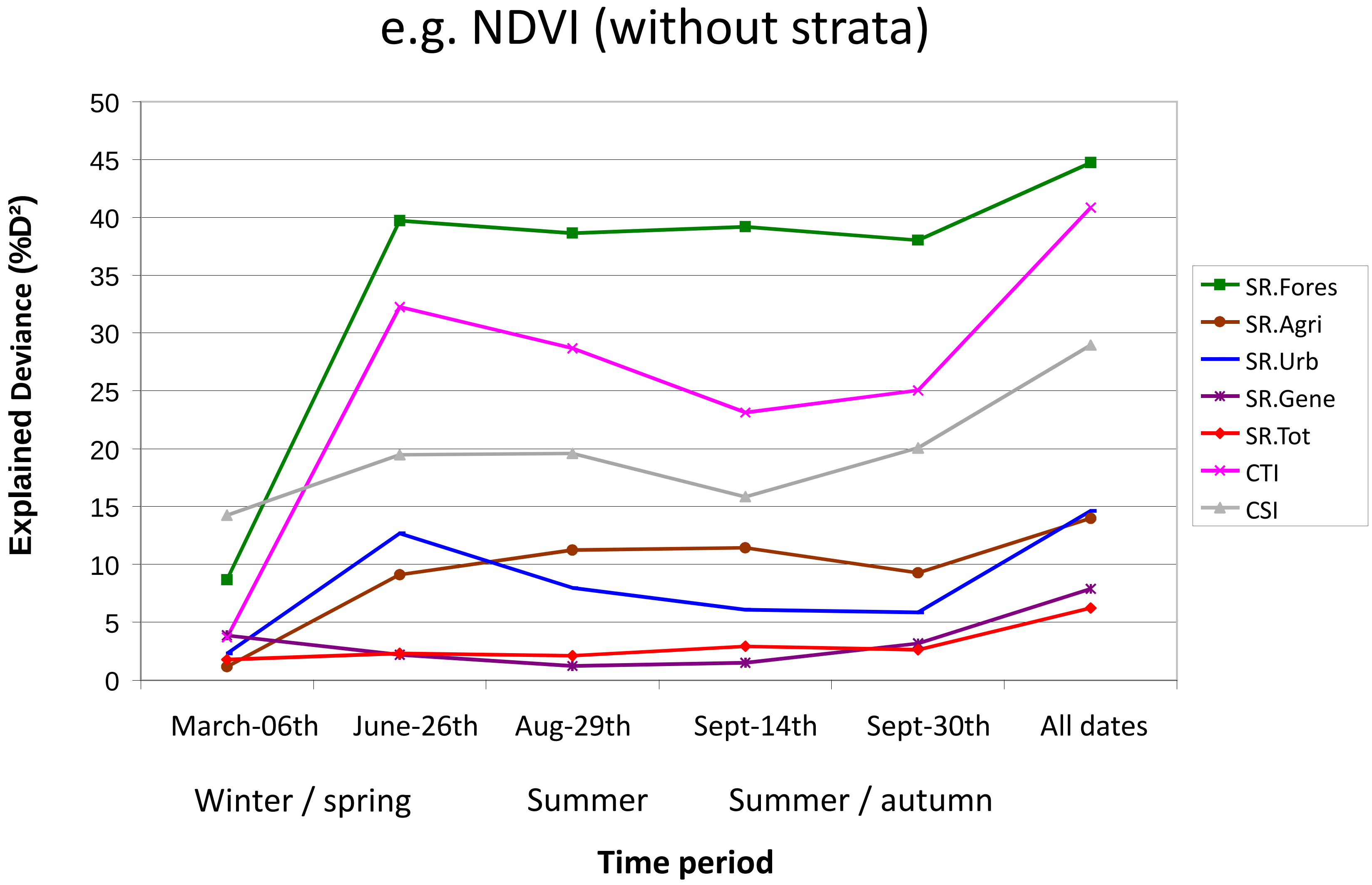
5. Results

Comparison: *continuous* **versus** *discrete representation*



5. Results

Best acquisition period



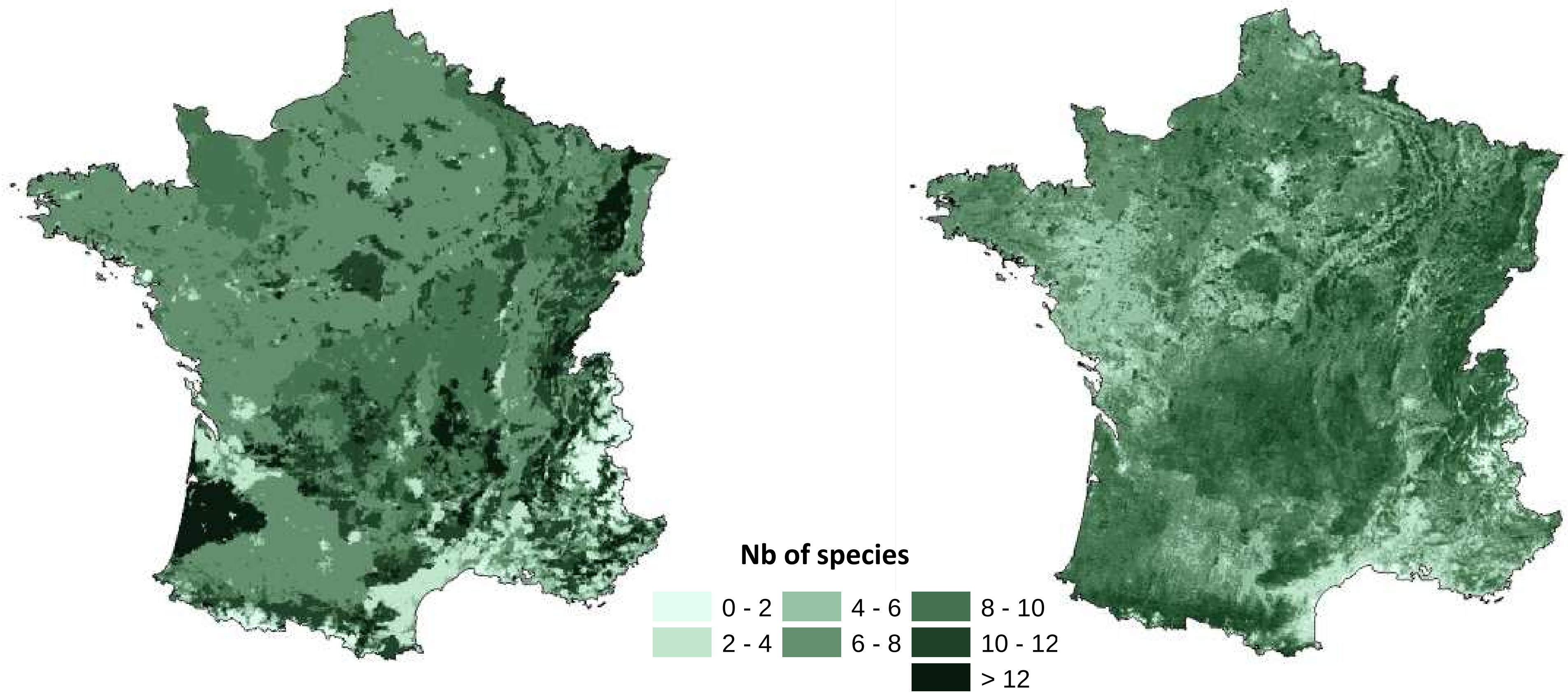
5. Results

Toward mapping bird species richness at national scale

e.g. Species Richness of forest birds

CORINE data
D^2 = 29,8 %, AIC = 4605

NDVI at the best time period
D^2 = 44,6 %, AIC = 4414



Conclusions

- Bird richness patterns are **always better explained by continuous data**
  - $\Delta\%D^2$ = 17% between VCF and CORINE for SR.Fores
  - $\Delta\%D^2$ = 21% between VCF and CORINE for SR.Agri
  - $\Delta\%D^2$ = 25% between VCF and CORINE for SR.Urb

- Model performance using the **VCF product** (continuous data) **is always better** than other data
  - Small difference with NDVI for SR.Fores ($\Delta\%D^2$ = 4%) but higher difference for SR.Agri and SR.Urb ($\Delta\%D^2$ = 16%)

Conclusions

- **Functional classification** (discrete representation) is another alternative **to explore more deeply**
  - Always better performance than CORINE Land Cover
  - Close performance to NDVI for SR.Fores, SR.Agri, SR.Urb

- **Strong influence** of the data **acquisition period** as well as the use of **strata**
  - e.g. +32% (D^2) for SR.Fores with the best period
  - e.g. +13% (D^2) for SR.Agri with strata

Outlook

- Dealing with **spatial autocorrelation** (Dormann et al. 2007)
- Including **additional environmental variables**
- Exploring **phenological variables**
- Testing and assessing the models for **other years**

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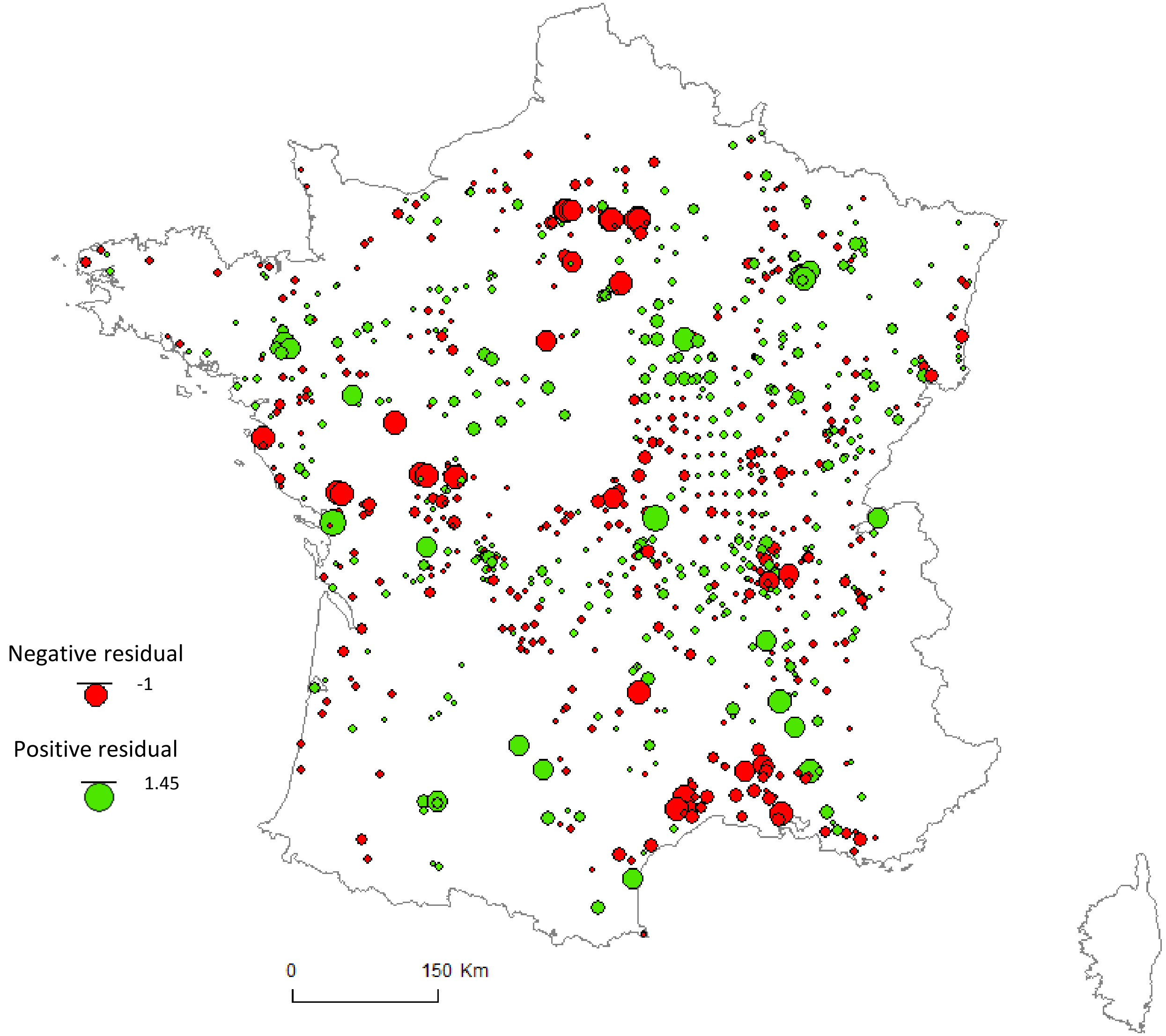

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Thank you!

Any questions?

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5. Results

Best acquisition period

Var réponse \ Var explicative	NDVI	EVI	LSTD	LSTN
RS.Fores	**177**	177	241	241
RS.Agri	**257**	065	257	257
RS.Urb	177	177	177	**241**
RS.Gene	**065**	065	065	257
RS.Tot	257	273	241	**065**
CTI	177	177	**241**	241
CSI	**273**	177	177	241

065 : début mars (en bleu) - 177 : fin juin (en vert) - 241, 257 et 273 : de fin août à fin septembre (en orange)
Les dates en gras correspondent aux synthèses donnant le meilleur modèle par variable réponse.

5. Results

Data complementarity (without strata)

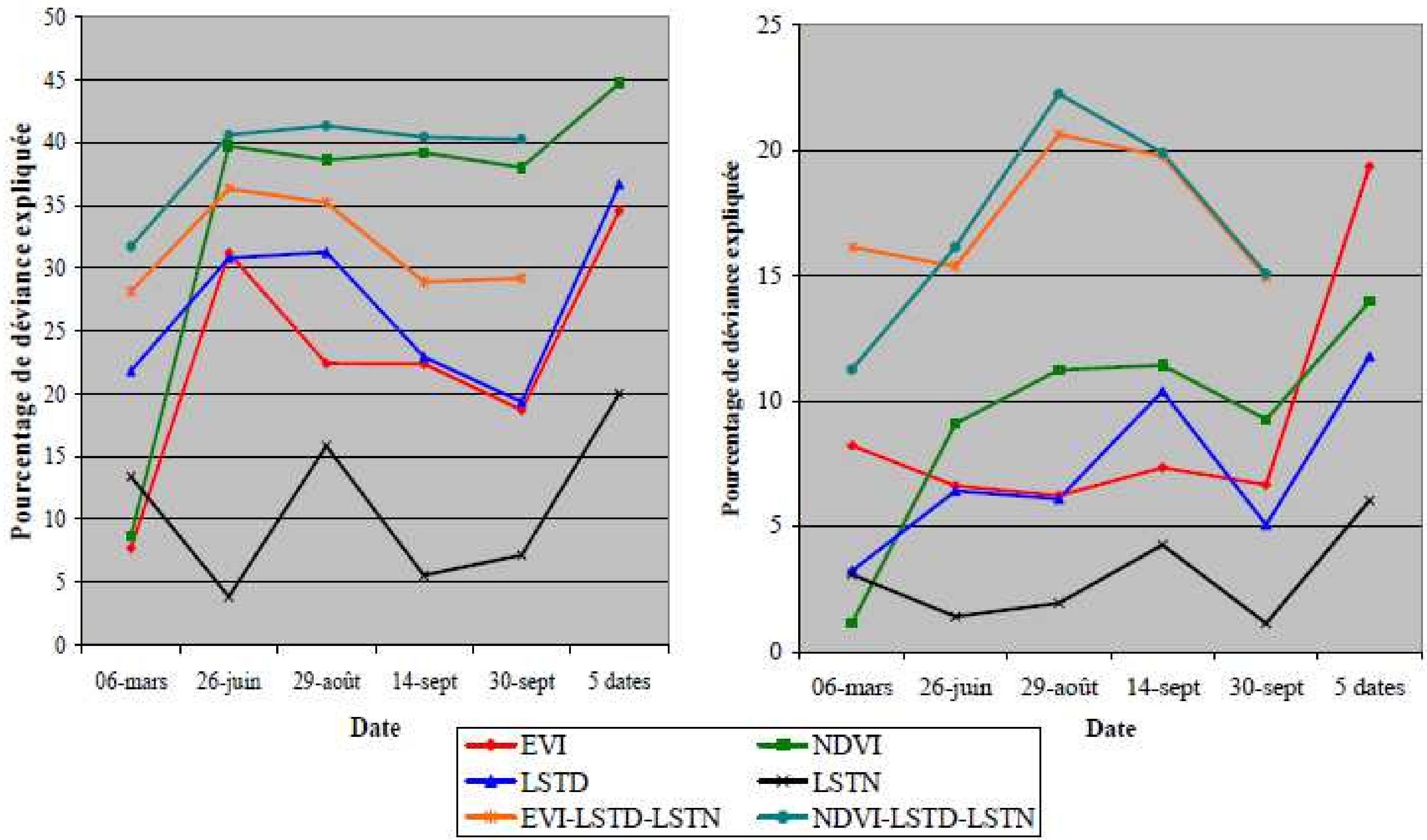

Figure 24 : D^2 des modèles de RS.Fores (à gauche) et RS.Agri (à droite)

5. Results

Predictive power: Spearman's *Rho* and *RMSE* (3-fold cross-validation)

Variable réponse	Type de stratification	Données utilisées dans le modèle	Rho moyen	RMSE moyen
RS.Fores	Régions climatiques	NDVI-177	**0,687**	**2,86**
		EVI-177	0,618	3,08
		LSTD-241	0,614	3,10
		LSTN-241	0,487	3,41
RS.Agri	Régions agricoles	NDVI-257	**0,503**	**2,71**
		EVI-065	0,433	2,83
		LSTD-257	0,455	2,78
		LSTN-257	0,303	2,91
RS.Urb	Régions agricoles	NDVI-177	**0,479**	**2,85**
		EVI-177	0,414	2,86
		LSTD-177	0,461	**2,85**
		LSTN-241	0,247	3,09
RS.Gene	Régions agricoles	NDVI-065	0,323	1,91
		EVI-065	**0,392**	**1,88**
		LSTD-065	0,349	1,90
		LSTN-257	0,318	1,90
RS.Tot	Régions agricoles	NDVI-257	0,429	6,40
		EVI-273	**0,436**	**6,32**
		LSTD-241	0,356	6,49
		LSTN-065	0,379	6,42
CTI	Sylvo-écorégions	NDVI-177	0,654	0,26
		EVI-177	0,614	0,27
		LSTD-241	**0,711**	**0,24**
		LSTN-241	0,517	0,28
CSI	Régions agricoles	NDVI-273	0,480	**0,119**
		EVI-177	**0,502**	0,120
		LSTD-177	0,481	0,120
		LSTN-241	0,317	0,128

Les valeurs en gras correspondent aux meilleures valeurs par variable réponse

Functional diversity

Community Specialisation index

$$\mathrm{CSI}_j = \frac{\sum_{i=1}^{n} a_{ij}(\mathrm{SSI}_i)}{\sum_{i=1}^{n} a_{ij}}$$

where n is the total number of species recorded, a_{ij} is the abundance of individuals of species i in plot j, and SSI_i its specialization index.

SSI = Variation Coef. of the species density across habitat

Generalist species: little variation of densities
Specialist species: high variation of densities

Community Trophic index

Replace SSI by STI

STI based on the
position of a species within a trophic chain of 3 levels, those of vertebrates eating vegetables, invertebrates or vertebrates