Coupling historical prospection data and a remotely-sensed vegetation index for the preventative control of Desert locusts

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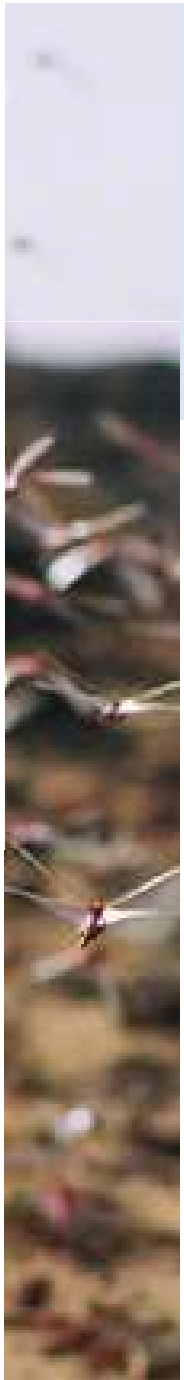

Introduction

- *Schistocerca gregaria*: major locust species

Gregarization

Introduction

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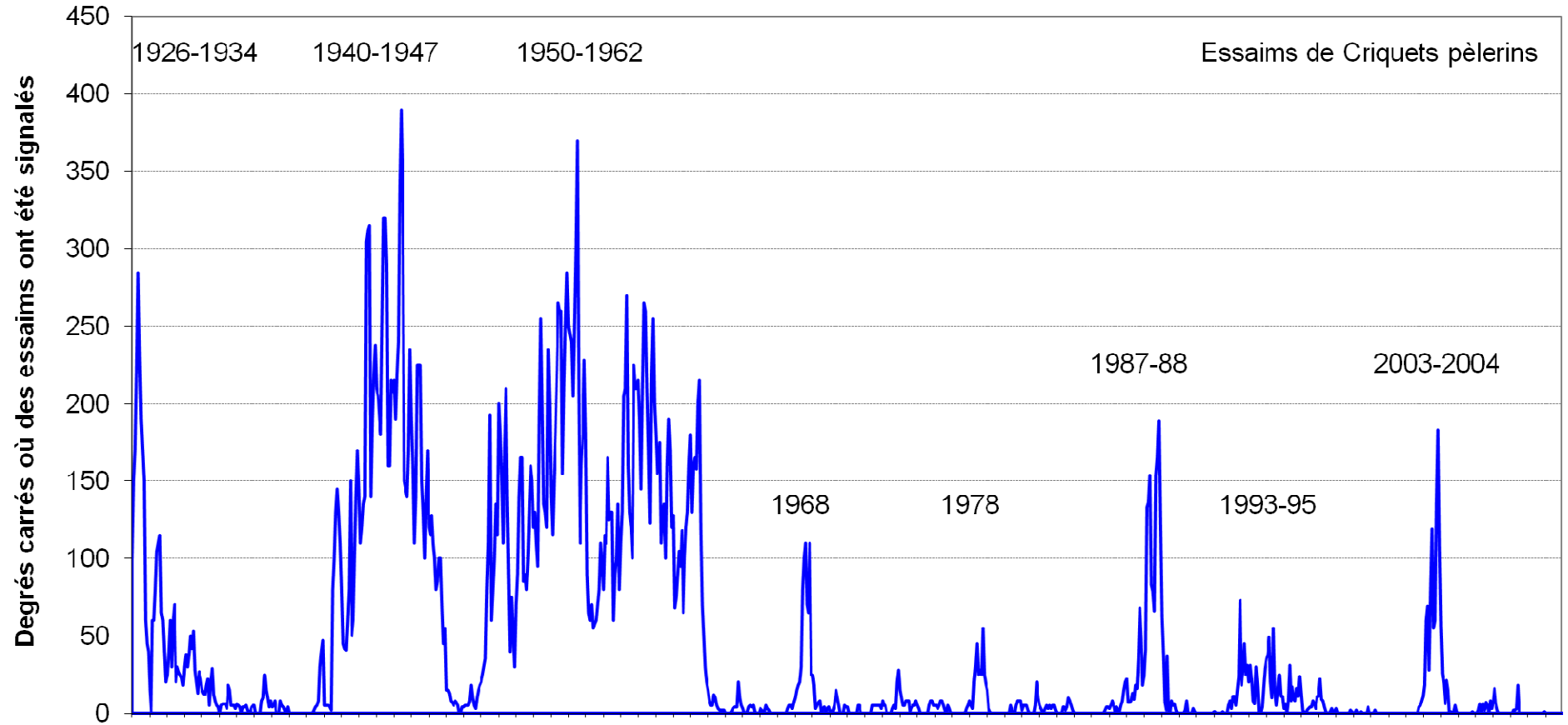
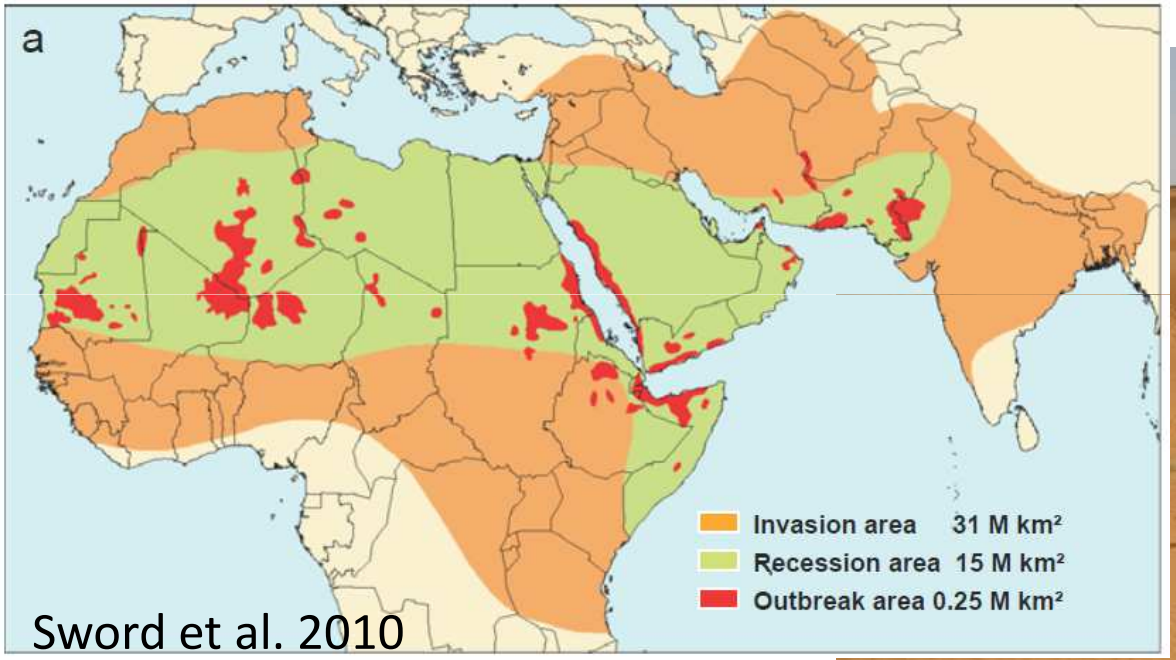
- Preventative management since 1960's



Tratalos et al. 2010

Introduction

- *Schistocerca gregaria*: major locust species
- Preventative management since 1960's
- Large distribution area: Where to survey?



Sword et al. 2010

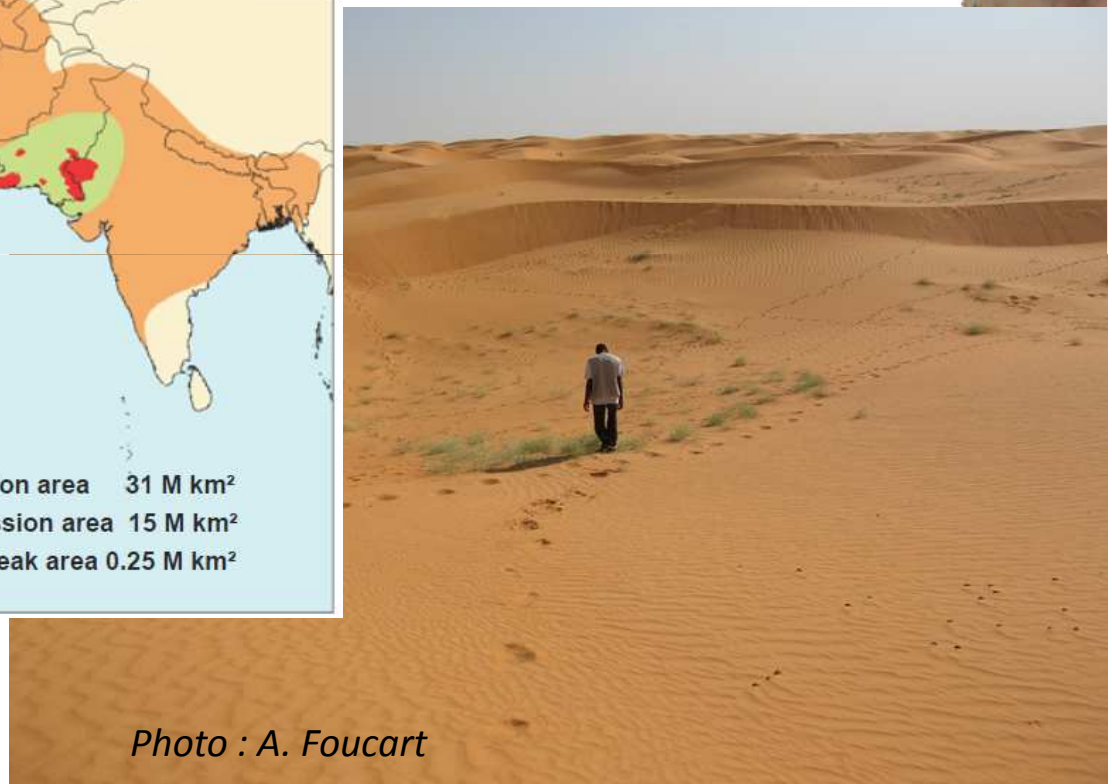
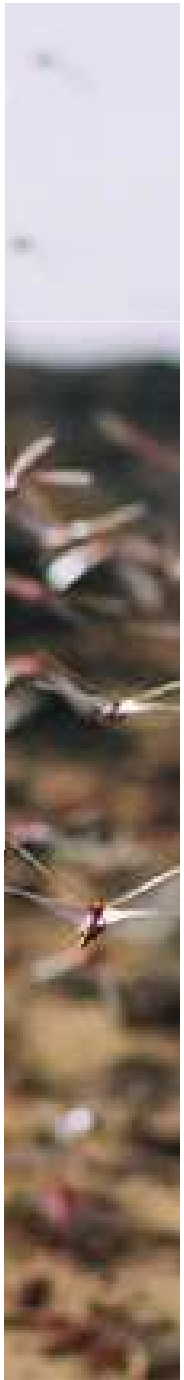
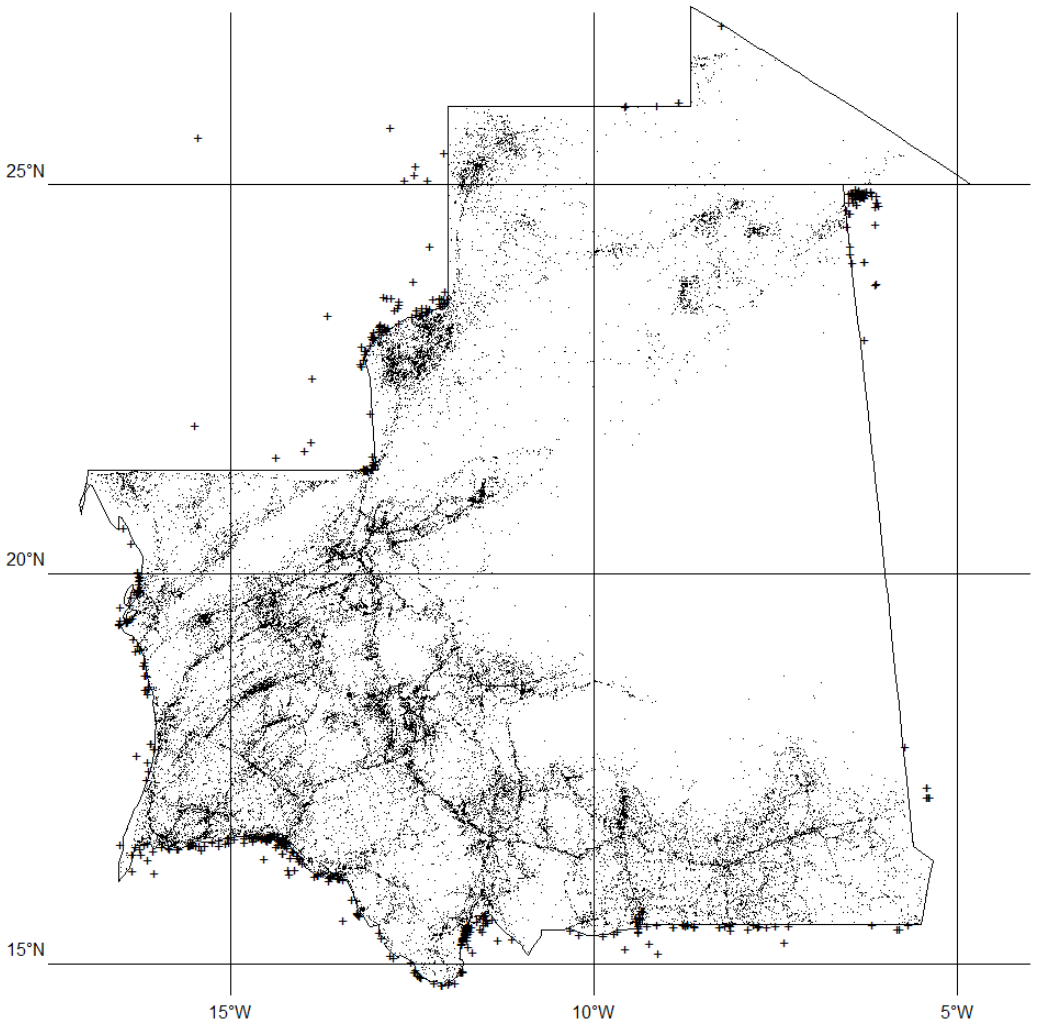


Photo : A. Foucart

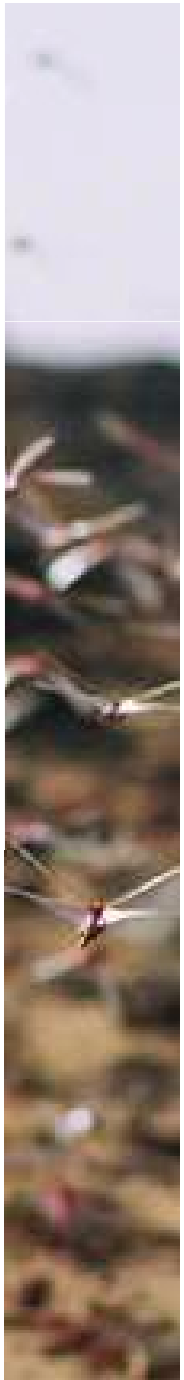
Introduction



- Prospection data in Mauritania since 1988
- Bias of prospection:
  - Target oriented
  - Seasonal
  - Accessibility
- Used to characterize habitats (e.g. Babah 2008)
- But never directly used in combination with satellites data

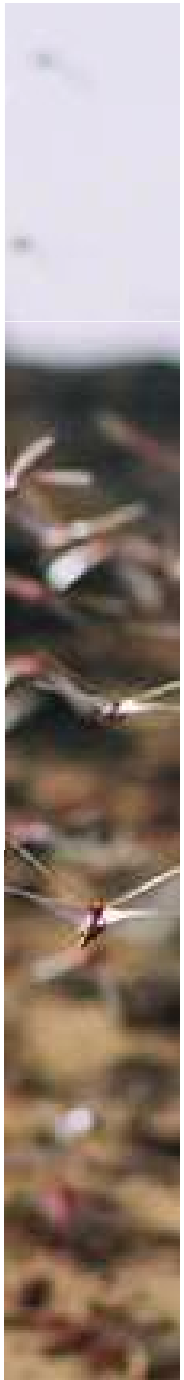


Introduction



- Remote sensing has long been discuss as a help to focus surveys:
  - Development of ARTEMIS by FAO based on Meteosat and NOAA-AVHRR satellite data from 1975 (Tucker et al. 1985, Hielkema 1990)
  - Regional 1980/1981 upsurge correlated to NDVI (normalized difference vegetation index) at Global Area Coverage (GAC, 4km resolution) (Hielkema et al. 1986)
  - Number of pixels with NDVI > 0.09 or 0.13 (at 7.4km resolution) explained locust presence in Red Sea area during 1980's-1990's (Despland et al. 2004)
  - But Tratalos et al. (2006) demonstrated that GAC-NDVI does not explain overall locust presence (at 8km resolution)
- One major recent advances (since 2000) is the higher resolution of MODIS – NDVI (250m resolution) + free access
  - MODIS images used in FAO's early warning system (Cressman & Hodson 2009)

Introduction



- Objectives:
  - Identify information from vegetation structure(s) able to explain desert locust presence
  - Integrate these information on early warning system ➔ reduce the prospection area

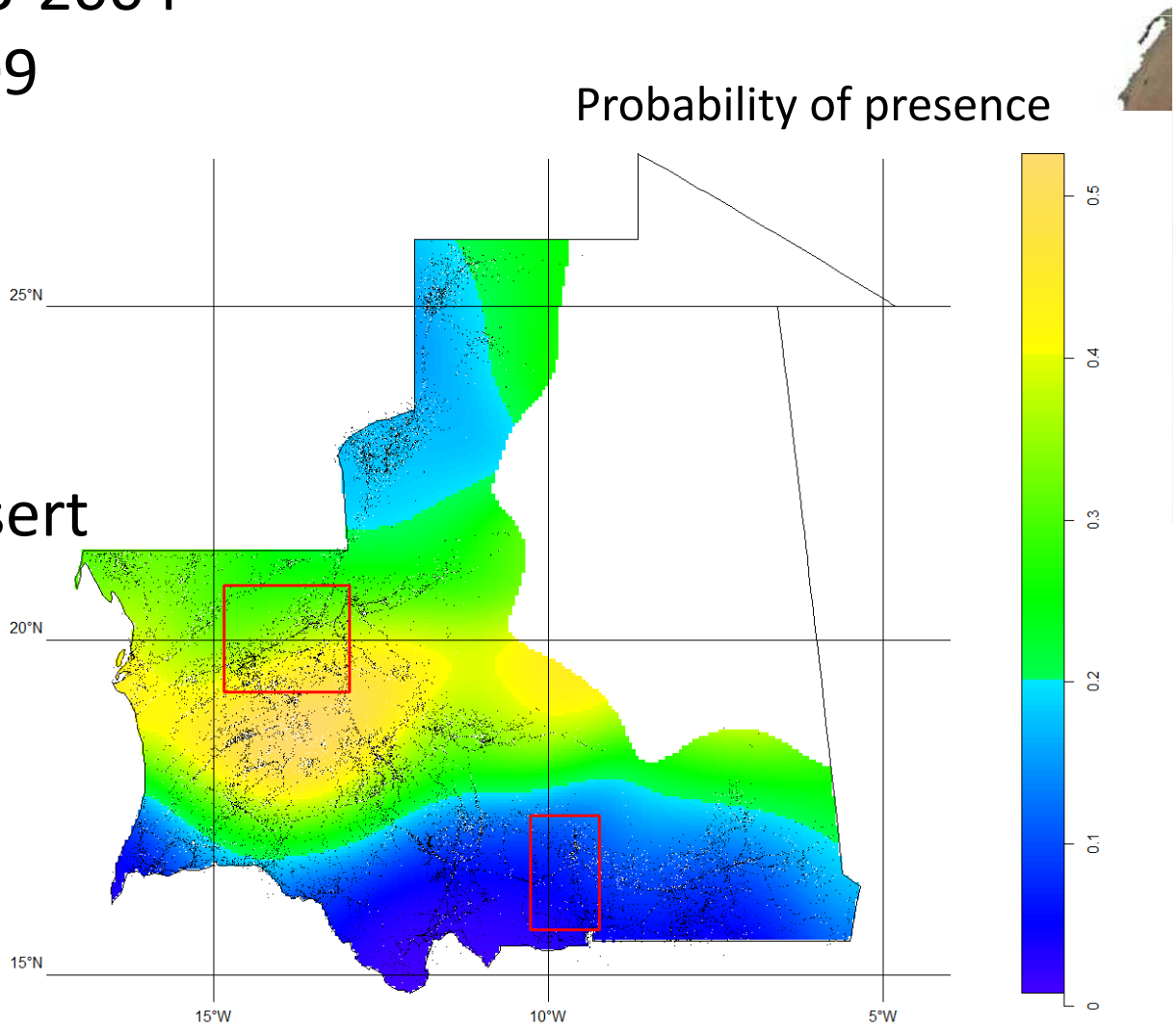
Methods

- MODIS from 2000
- Invasion period 2003-2004

➔Focus on 2005 – 2009 period

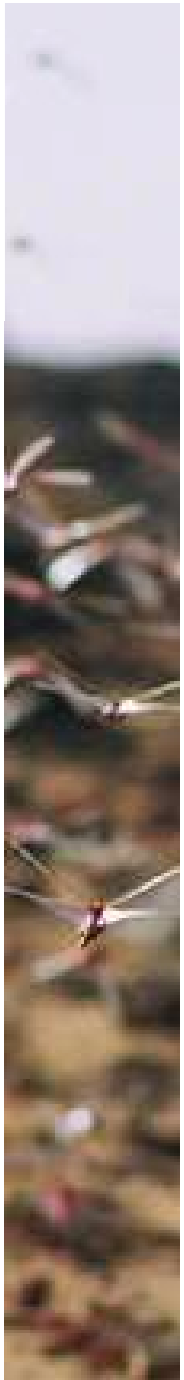
➔Focus on 2 working areas (representativeness)

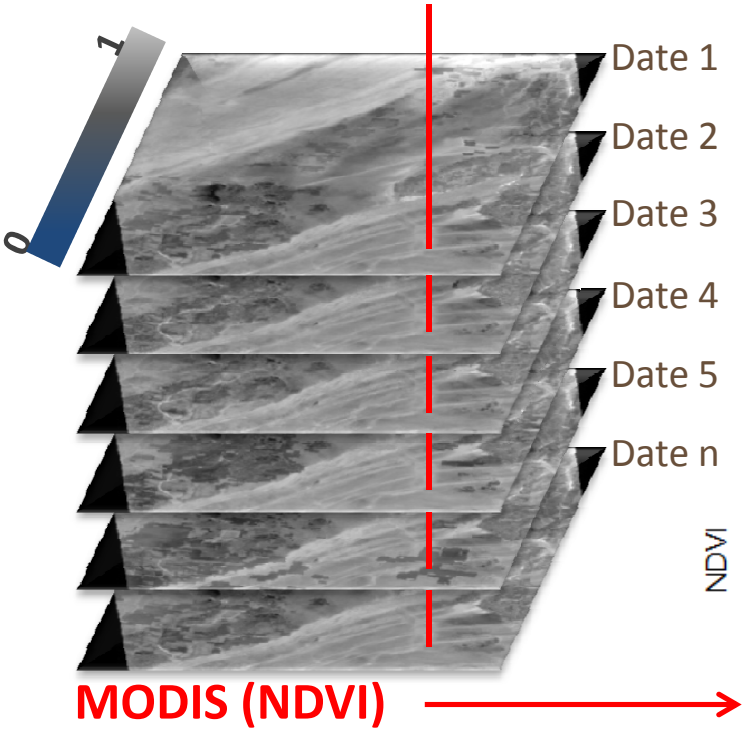
➔1769 points, 11% presence of desert locust

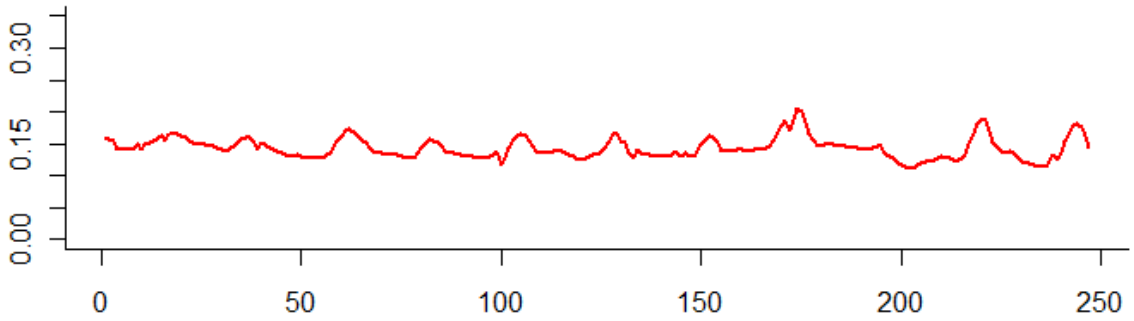


Methods

- NDVI data → every 16 days composite from MODIS satellites

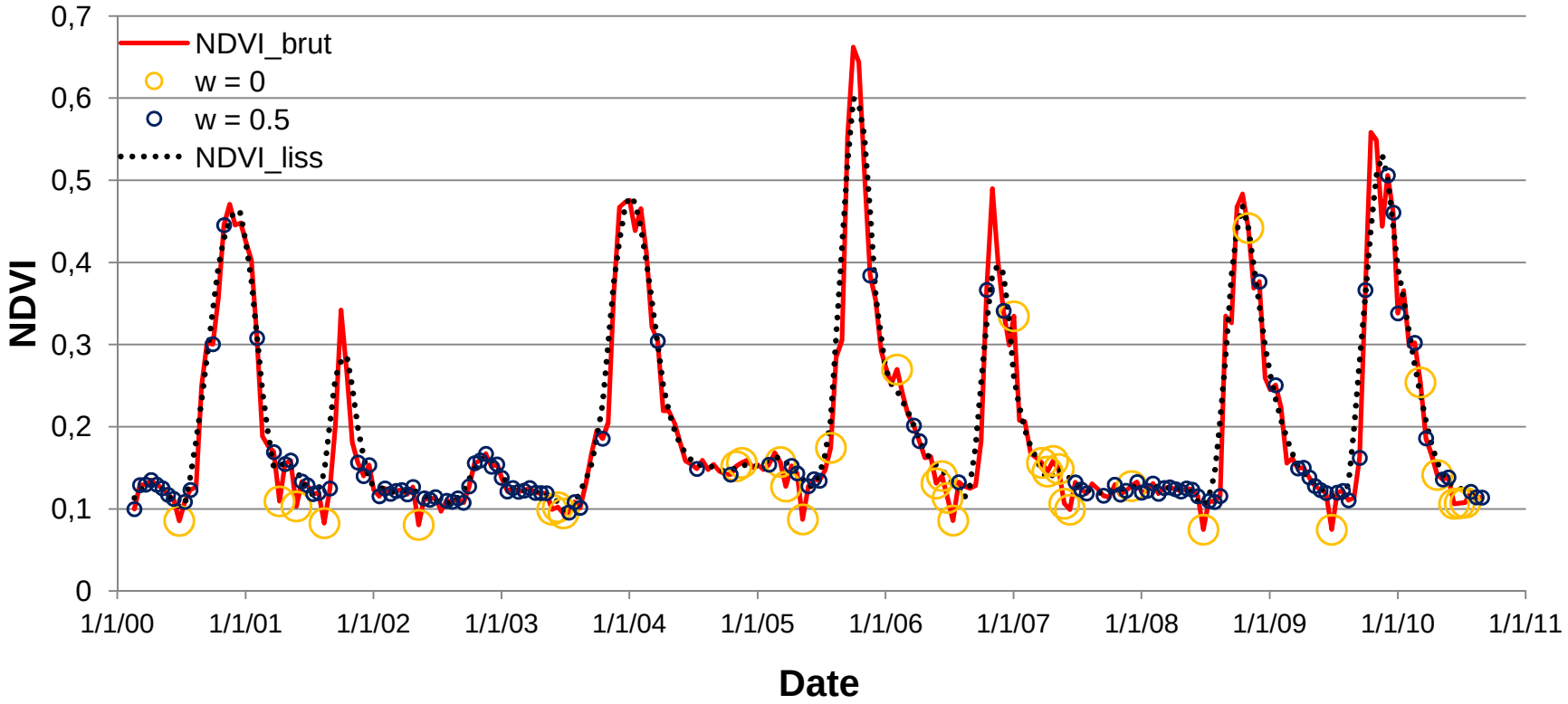






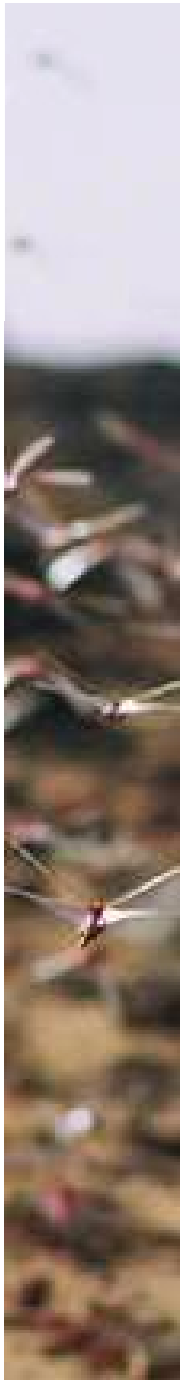
Methods

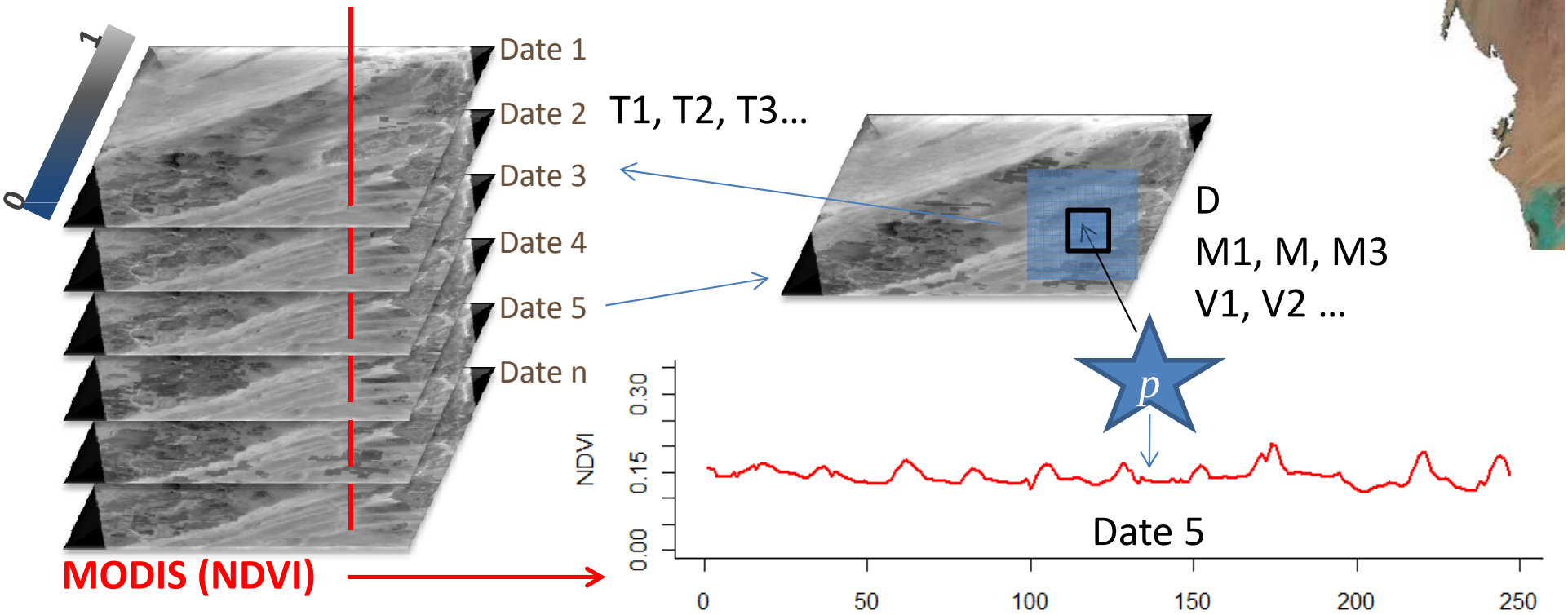
- Smoothing of time series:
  - First statistics to summarize these series:
    - minimum, maximum



Methods

- For each prospection point p, transformation of NDVI at t:
  - V = Proportion of vegetated pixels over 32x32 to 65x65 around p
  - M = Mean NDVI over 1x1 to 5x5 pixels around p
  - T = Proportion of change of M between t-2 and t-3
  - D = "Fractal Dimension" over 65x65 area (Despland et al. 2004)





Methods

- Logistic regression:

From: $\text{Logit}[\Pr(p = presence)] = \alpha_0 + \alpha_1 \cdot X$

To:

$$\text{Logit}[\Pr(p = presence)] = \alpha_0 + \alpha_1 \cdot T + \alpha_2 \cdot T^2 \quad \text{Temporal}$$

$$+ \alpha_3 \cdot M + \alpha_4 \cdot M^2 \quad \text{Local}$$

$$+ \alpha_5 \cdot V + \alpha_6 \cdot V^2 \quad \text{Structural}$$

$$+ \alpha_7 \cdot D + \alpha_8 \cdot D^2 \quad \text{Structural}$$

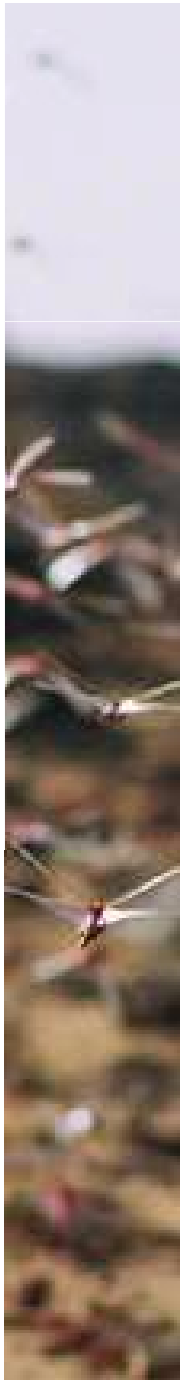
Static

$$+ \alpha_9 \cdot maxNDVI + \alpha_{10} \cdot maxNDVI^2$$

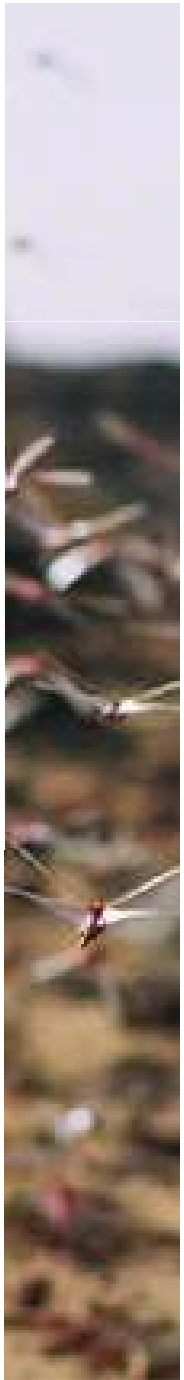
$$+ \alpha_{11} \cdot minNDVI + \alpha_{12} \cdot minNDVI^2$$

➔Brute force selection of variables

➔CAIC scores (Bozdogan 1987)



Results

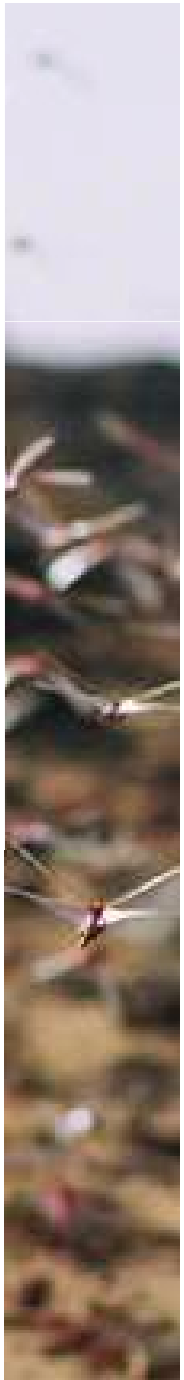


- Multi-model inference:
  - 10 Best models of 84774 possibles…

Best

Static variables	Large scale	Local	Temporal	CAIC
maxNDVI +		V52 + M2 + $M2^2$ + $Ts23_2$		2970.937
maxNDVI +		V60 + M2 + $M2^2$ + $Ts23_2$		2972.880
maxNDVI +		V52 + M2 + $M2^2$ + $Ts23_1$		2973.401
		V32 + M2 + $M2^2$ + $Ts23_2$ + $Ts23_2^2$		2973.538
maxNDVI +		V56 + M2 + $M2^2$ + $Ts23_1$		2973.962
minNDVI +		V36 + M2 + $M2^2$ + $Ts23_2$ + $Ts23_2^2$		2977.250
maxNDVI + minNDVI +		V36 + M2 + $M2^2$ + $Ts23_2$		2977.616
maxNDVI +		V36 + M2 + $M2^2$ + $Ts23_2$ + $Ts23_2^2$		2978.312
minNDVI +		V32 + M2 + $M2^2$ + $Ts23_2$ + $Ts23_2^2$		2978.816
maxNDVI + minNDVI +		V32 + M2 + $M2^2$ + $Ts23_2$		2979.079

Results



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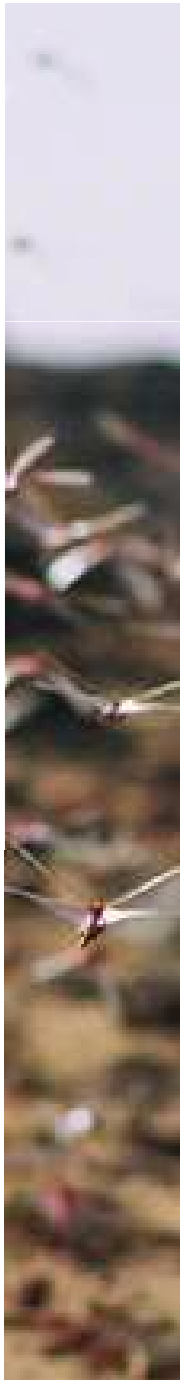
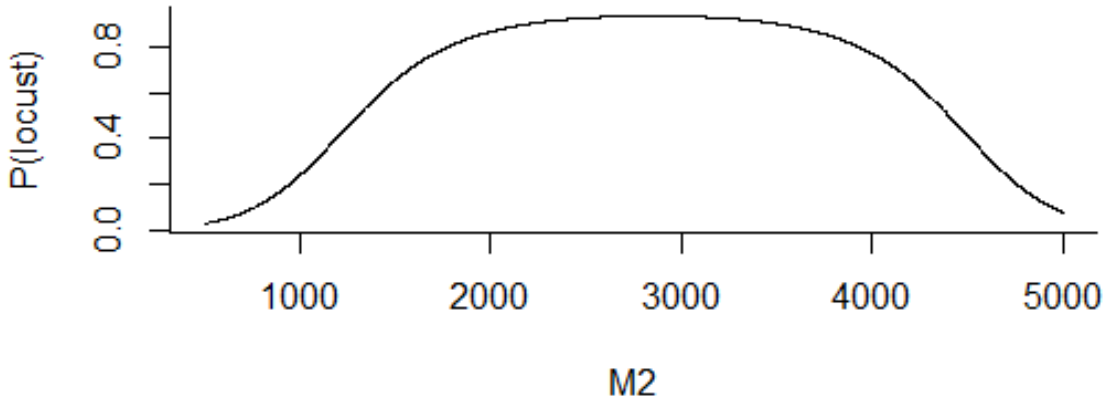


maxNDVI + V52 + M2 + $M2^2$ + $Ts23_2$

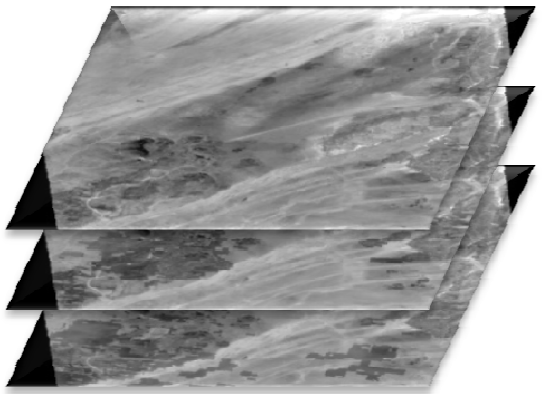
	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-6.432e+00	4.394e-01	-14.636	< 2e-16	***
maxNDVI	-2.340e-04	1.147e-04	-2.039	0.0414	*
V52	-4.620e+00	3.359e-01	-13.755	< 2e-16	***
M2	6.406e-03	5.906e-04	10.847	< 2e-16	***
$M2^2$	-1.123e-06	1.352e-07	-8.306	< 2e-16	***
$Ts23_2$	8.502e+00	1.404e+00	6.056	1.39e-09	***



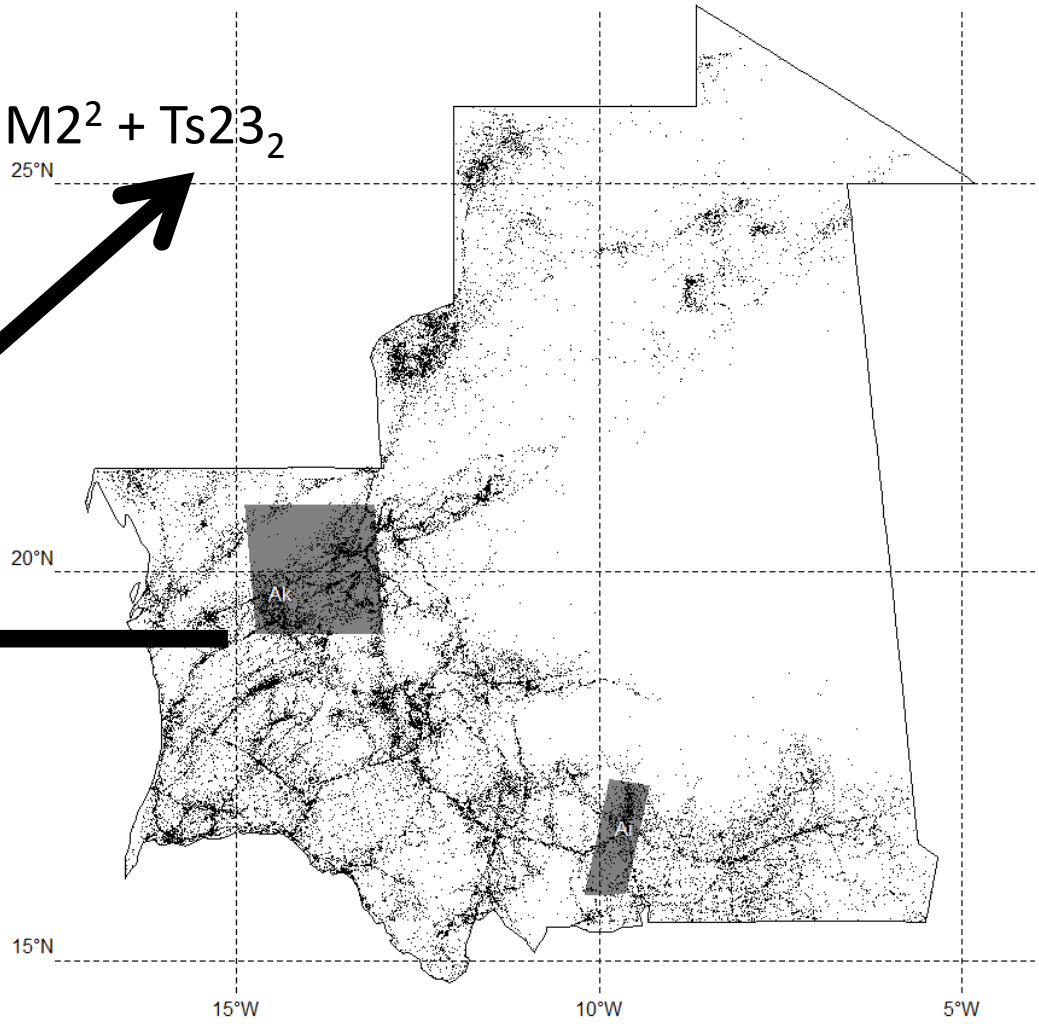
Results - Prediction

Historic NDVI data

maxNDVI + $V52 + M2 + M2^2 + Ts23_2$



September 2010



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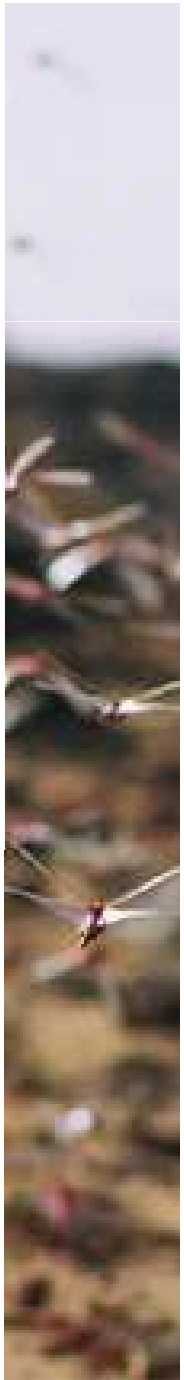
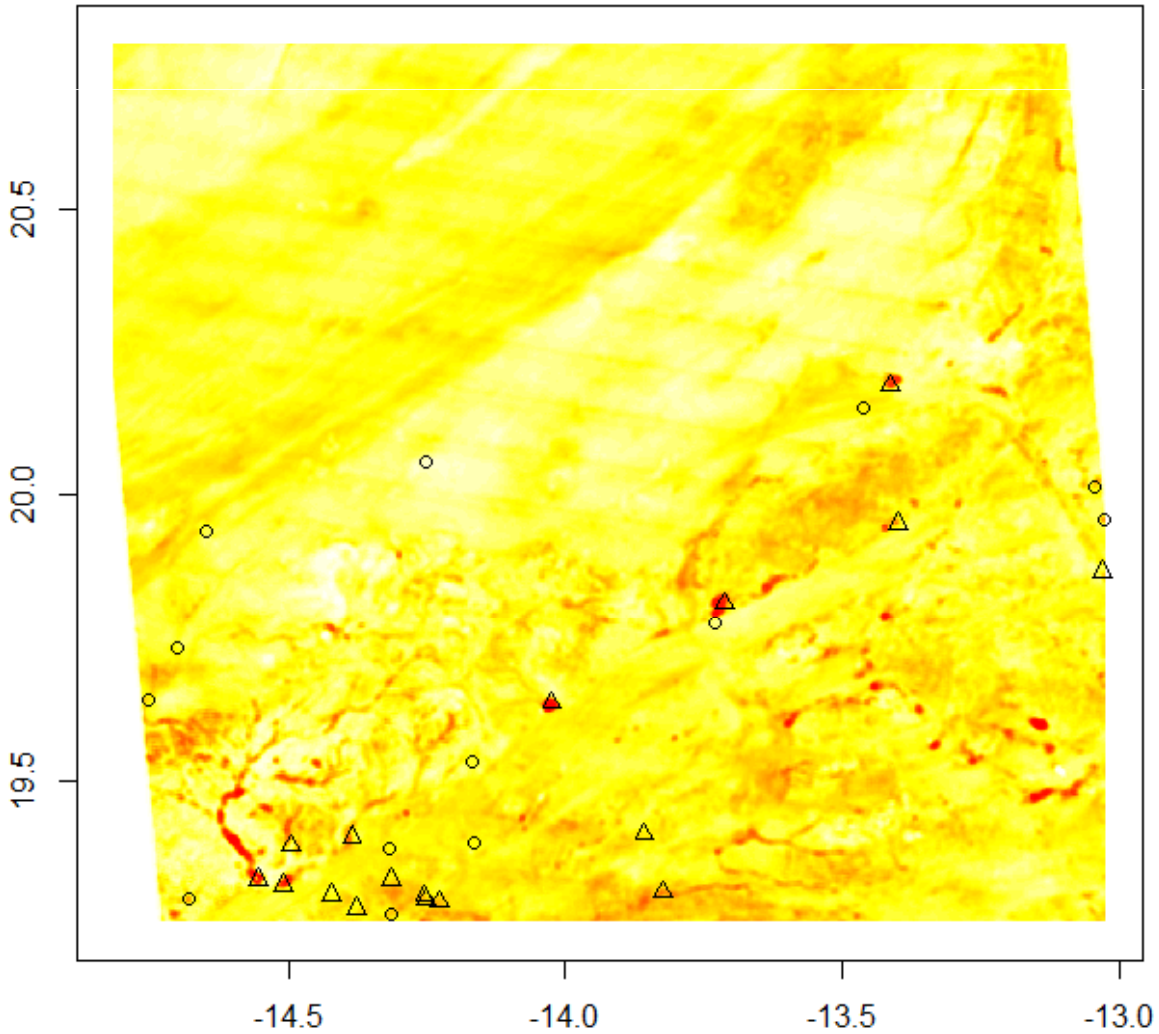
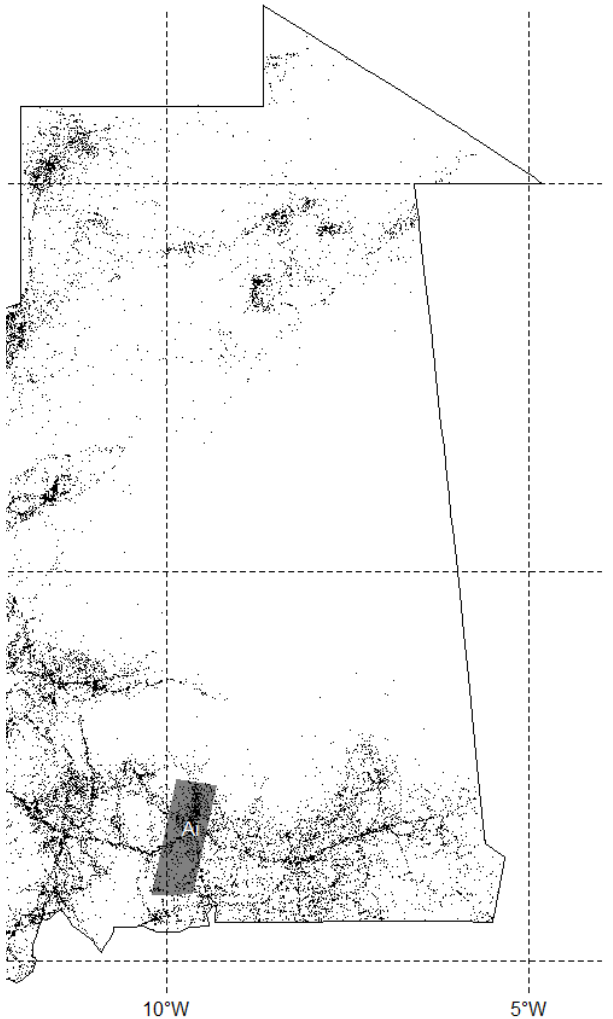
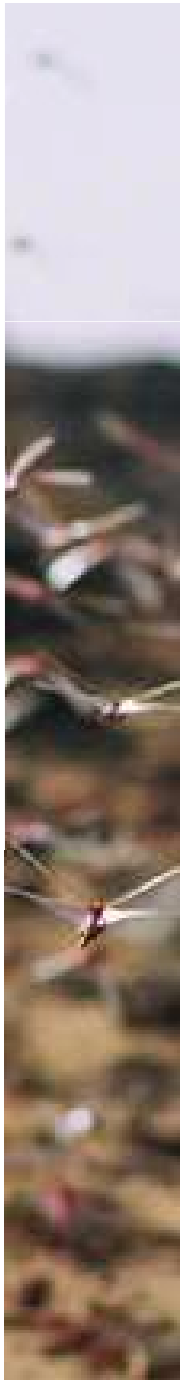






1st Discussion



- First results show:
  - Potential of explanation of local NDVI value (with intermediary level of vegetation)
  - Importance of temporal changes (with intermediary speed of increase in vegetation)
  - Implication of large scale vegetation
  - Possibility to use the static maps of NDVI statistics as background habitat influence

2nd study

Présence/Absence

Projet FFEM

Axe d'intégration spatiale et finalisation

Comment transférer les prédictions de fine à grande échelle ?

Axe d'amélioration méthodologique sur le terrain

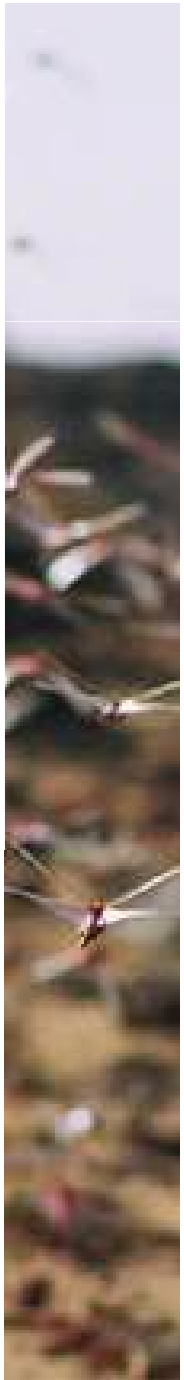
Quels indicateurs de la végétation permettraient de prédire rapidement le risque de grégarisation ?

Quelles conditions de végétation favorisent la grégarisation ?

Axe d'amélioration statistique

Quelle est l'importance des processus de propagation par rapport aux conditions de végétation ?

Méthode (2)



Hypothèse centrale

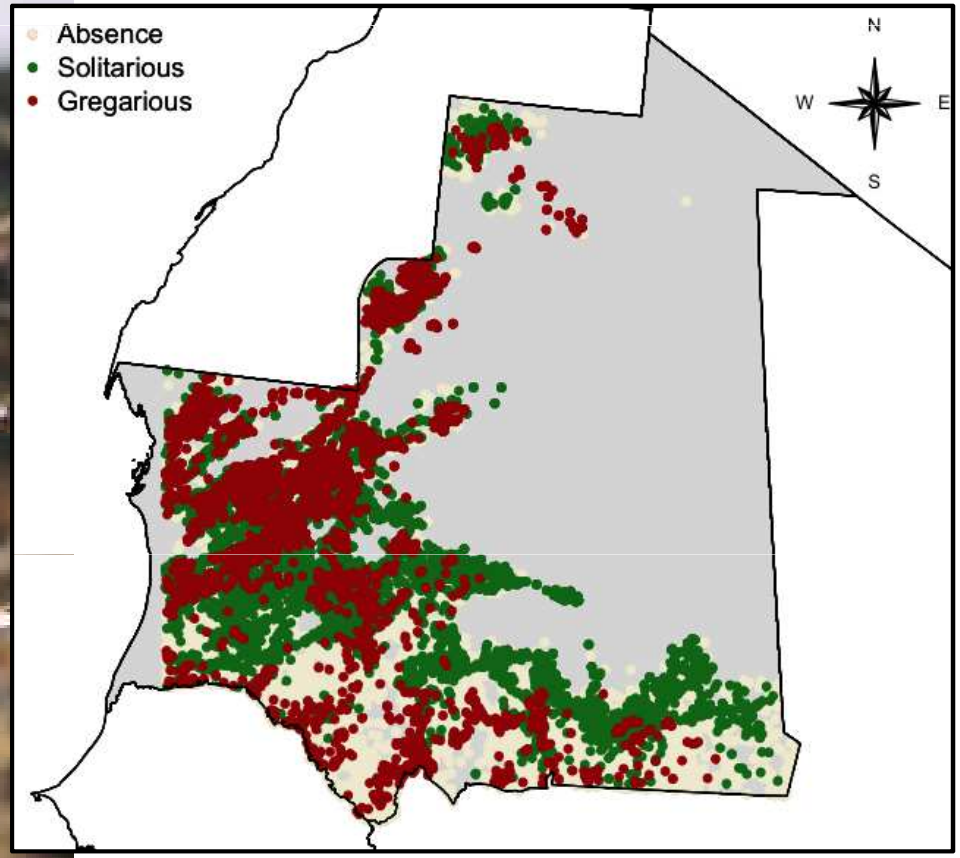
P(absence|solitaire|grégaire) ~ caractéristiques de l'habitat telles que mesurées à l'aide du NDVI

Approche statistique

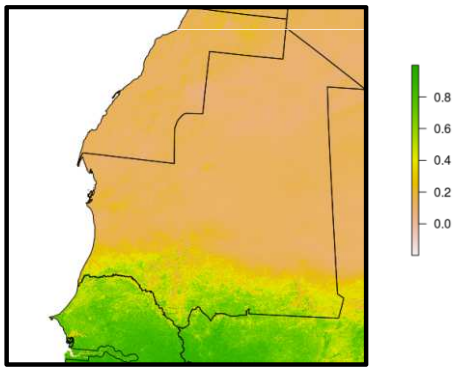
- Modèle log-linéaire multinomial (*Lee et al. 2013*)
- Jeu de donnée entier 2000-2011 pour « apprentissage » et 2012 pour validation
- Integration/correction autocorrelation spatiale

Méthode (2)

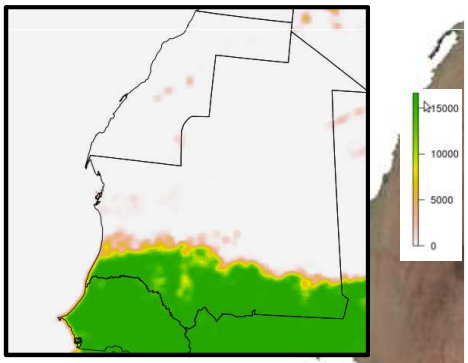
- En “pratique”



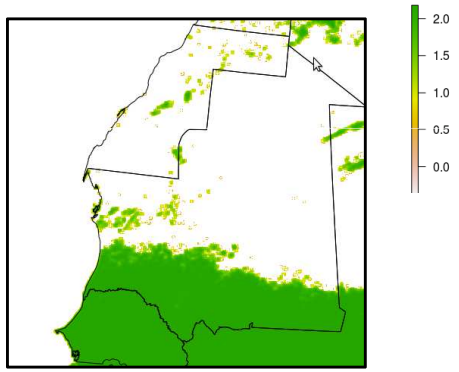
Points de prospection (db RAMSES)



Static layer (Max. NDVI)



Large scale NDVI [64 pix]

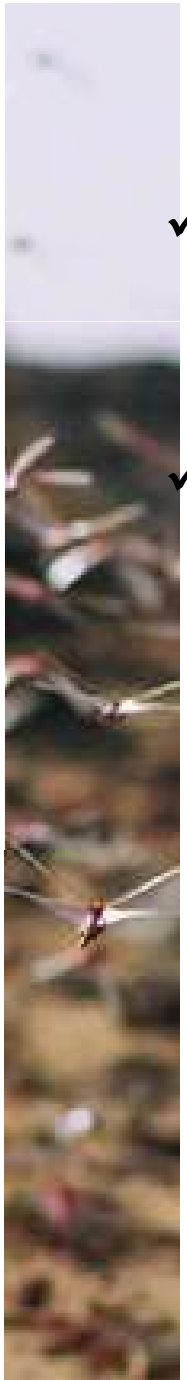


Fractal dimension

...

Variables explicatives calculées sur base du NDVI

Résultats

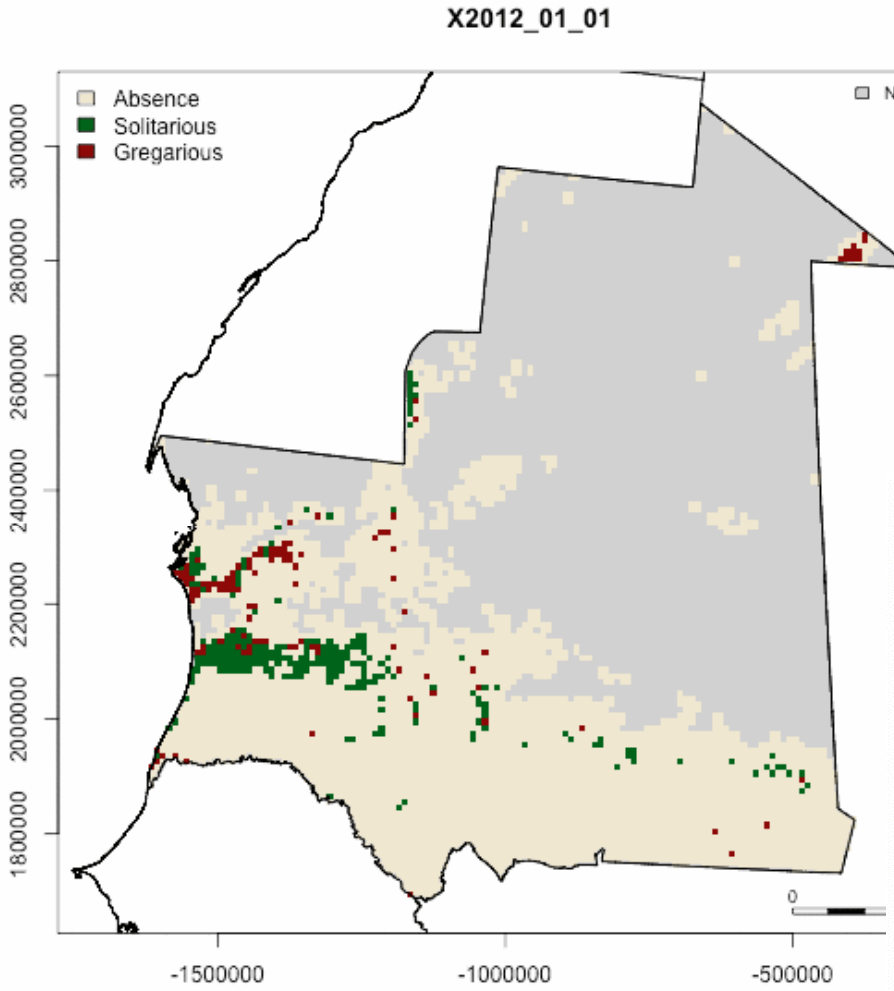


- ✓ 150 000 modèles ont été évalués sur base de ~37 000 points d'observation sélectionnés entre 2000 et 2011 en Mauritanie;
- ✓ Les 100 meilleurs modèles incluent la dimension fractale, ainsi que le carré des valeurs de variables retenues. Par exemple:

Coefficients	Solitarious	Gregarious
(Intercept)	-2.43	-1.04
NDVI.Max	-9.39	-32.45
I(NDVI.Max^2)	2.87	30.75
NDVI.Min	-1.97	-8.62
I(NDVI.Min^2)	-7.28	-71.32
FD	-0.20	-1.47
I(FD^2)	0.14	1.25
myNDVI.V64	0.00	-0.00
I(myNDVI.V64^2)	-0.00	-0.00
myNDVI.M1	35.36	50.56
I(myNDVI.M1^2)	-47.48	-56.34
Ts3_2	0.61	-5.27
RAC.mutli	-2.53	-3.34
RAC.mutli.upd.2	-0.33	-0.38

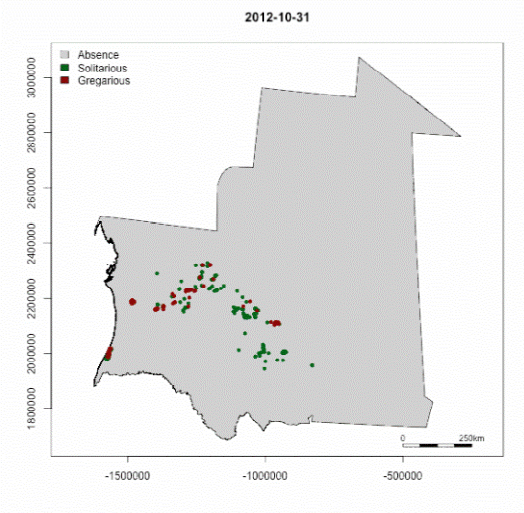
Résultats

✓ Dynamique spatio-temporelle des prédictions pour 2012

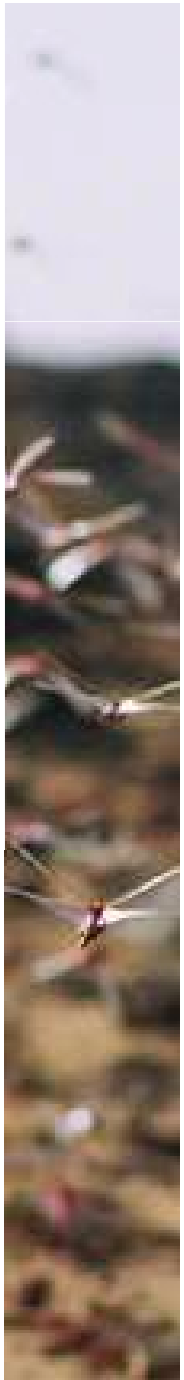


Distribution prédite par le modèle

Valeurs observées



Discussion & Perspectives



Prédire la distribution spatiale du criquet pèlerin en phase grégaire à l'aide d'indices de végétation issus de la télédétection

- Approche réduisant le nombre de faux négatifs par comparaison à l'approche tenant compte uniquement des présences/absences (e.g. *Piou et al. 2013*);
- Approche libre d'accès (NDVI, R Cran Project)

- Hierarchical Bayesian and State-Space models:
  - Simulating prospection choices
  - Phase change from prospection data (presence solitarious → presence of gregarious)
- Integration of simplified version of this kind of model in RAMSES-GIS of FAO for early identification of critical areas

Thank you …
Merci de votre attention