Estimating seed dispersal at the landscape scale: the case of fereal oilseed rape populations

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Introduction

- European agro-ecosystems are mosaic of biodiversity compartments : (fields, margins, fallows, woods, roadsides …) where genes flows occur by pollen and seeds flows. Seed dispersal is responsible for the escape of cultivated species from crops (i.e. feral populations) and therefore could induce genetic pollution and modifications of road verge plant communities.
- This could enhance GMHT plants introduction consequences on natural, semi-natural and cultivated areas by a higher ability of these plants to colonise habitats under herbicide pressure.
- We built a seed flow model adapted to cultivated species based on mating models (Burczyk *et al*, 2006) to estimate seed dispersal distances of oilseed rape associated with different types of seed sources at the landscape scale.
- We used dispersal kernels which are particularly effective tools in modelling dispersal processes because they allow accounting for the rare but so important long-distance dispersal events (i.e. the tail of the kernel), which notably govern the spread rate of populations and gene flow at long distances.

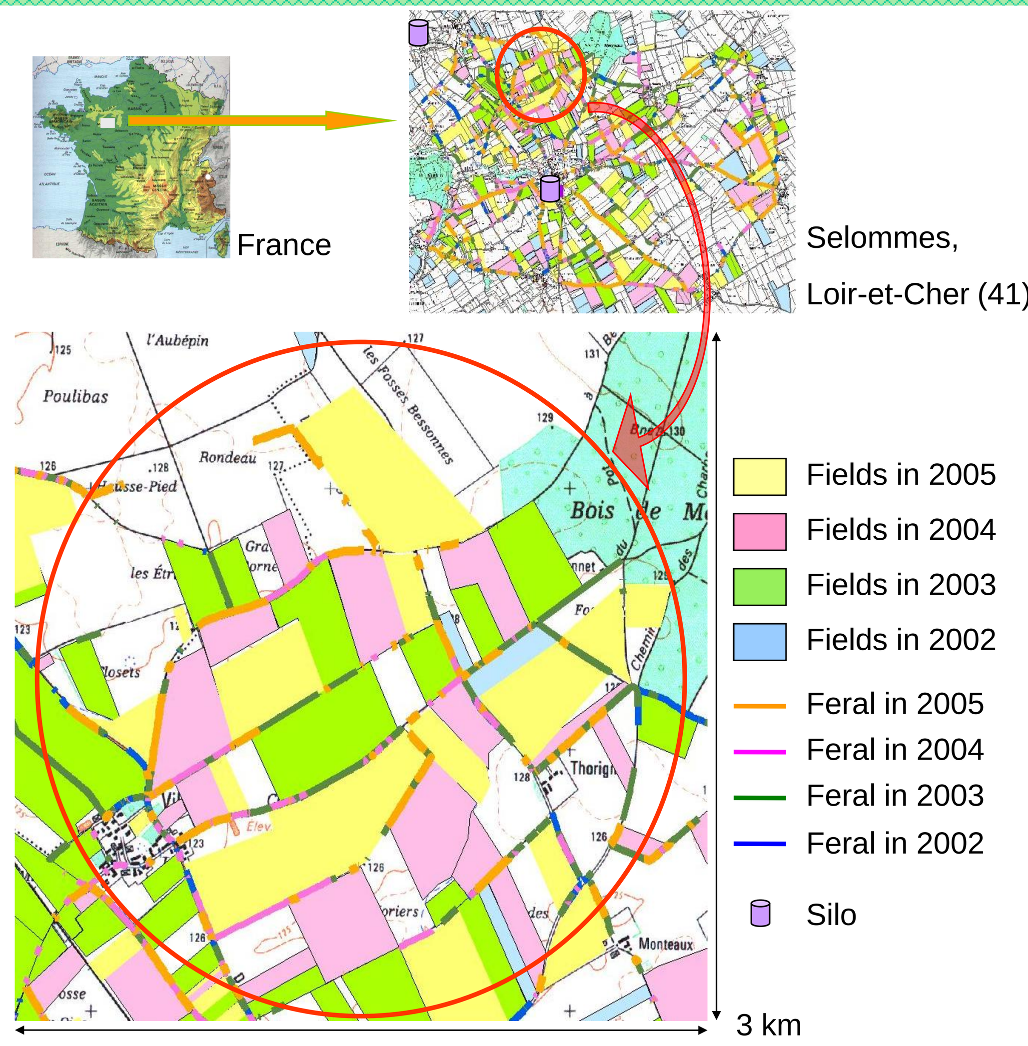
An agro-ecosystem : photography of Selommes area, June, 2009

Feral population of oilseed rape growing along a roadside

Methods I

Data obtention

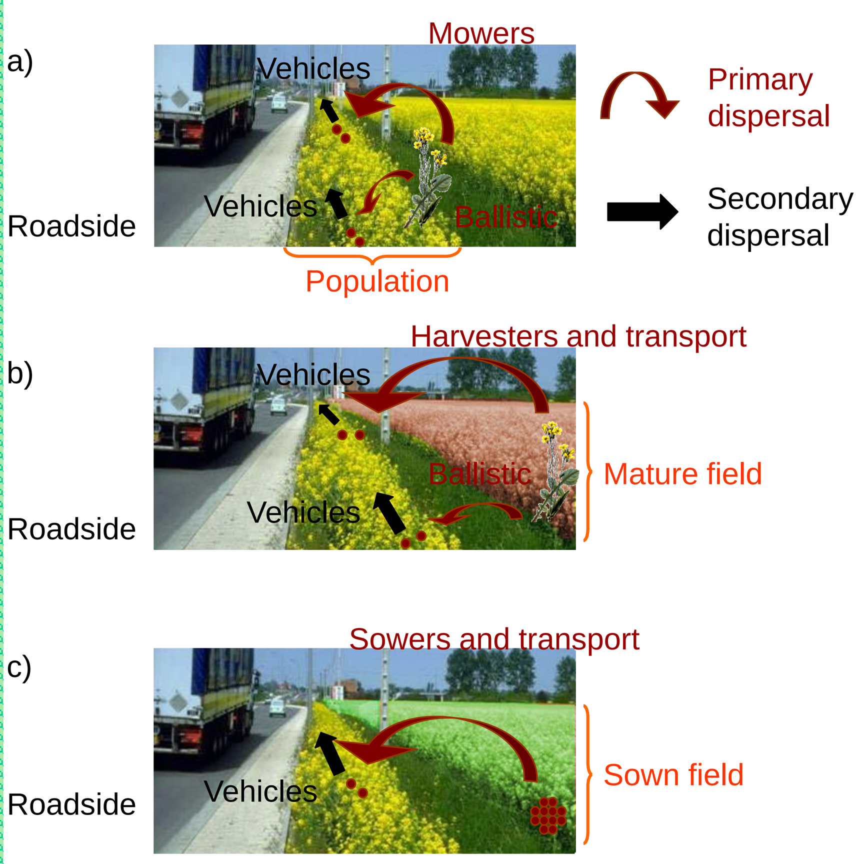
- Survey of an agro-ecosystem area of 41 km^2 around Selommes town and its silo
- GPS mapping of all oilseed rape fields and populations from 2000 to nowadays
- Sample collections of leaves and seeds from 2002 to nowadays
- A cultivar database from seed producers (58 cultivars)
- Samples and cultivars were genotyped with 8 microsatellites markers :
  - 2125 sample genotypes (2002-2005, sub area)
  - 1480 cultivar genotypes
- Samples assignation to cultivars with Likelihood method (Devaux et al., 2005) :



Oilseed rape fields and feral populations from 2002 to 2005 in Selommes and study areas

Methods II

Seed Dispersal Model



Seeds dispersal mechanisms, seeds from a) feral population, b) mature field, c) sown field

Model parameters :

$$k_i(z) = \frac{1}{a}\exp\left(\frac{-|z|}{a}\right)$$

ki(z) : dispersing seeds proportion
z : dispersal distance
a : mean dispersal distance

Seed dispersal kernel : exponential function

Field in *x* — Feral

$$C_{i,x,y} = \int_{d_{min(x,y)}}^{d_{min(x,y)}+L} k_i(z)dz$$

C : field seed contribution
L : field border length
d : feral-field distance

Seed contribution of a feral beside a field

Field in *x*

$$C_{x,y} = \int_0^{d_{min(x,y)}} k_i(z)dz + \int_0^{L-d_{min(x,y)}} k_i(z)dz$$

x : relative position between the seed source *i* and the target feral plant *y*
y : feral barycenter

Seed contribution of a feral in front of a field

$$L(\alpha,ms,\sigma,a,i) = ms \times BSP + (1-ms)\times\left[\alpha\times\left(\frac{1}{1+\sigma+\sigma^2}C^{2004}_{x,y} + \frac{\sigma}{1+\sigma+\sigma^2}C^{2003}_{x,y} + \frac{\sigma^2}{1+\sigma+\sigma^2}C^{2002}_{x,y}\right) + (1-\alpha)\times C^{2005}_{x,y}\right]$$

L : feral plant *i* Likelihood
alpha : weigth of 2002-2004 fields relatively to 2005 fields
ms : Background Seed Pool (BSP) fraction
1-ms : Expected Seed Pool (ESP) fraction
a : mean seed dispersal distance
sigma : seed bank survival rate
C : field seed contribution

Likelihood of observing all feral populations of 2005 taking account of contributions from fields (ESP) and others sources (BSP) between 2002 to 2005

Preliminary Results

2005 Populations above 2004 data (Garnier, 2006)

$$L(\alpha,ms,a,i) = ms \times BSP + (1-ms)\times\left(\alpha\times C^{2004}_{x,y} + (1-\alpha)\times C^{2005}_{x,y}\right)$$

ms : contribution of the background seed pool
alpha : estimated weight of mature fields in 2005
C : field seed contribution

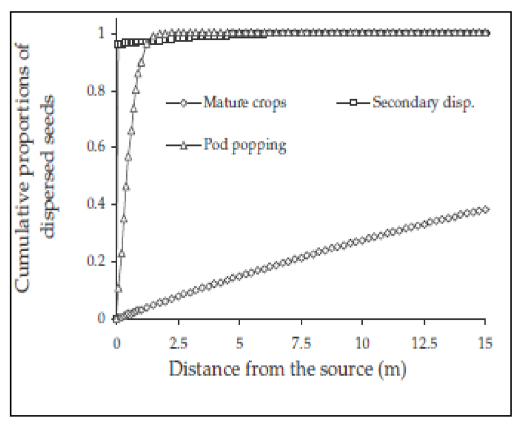
Likelihood of observing all feral populations of 2005 taking account of contributions from 2004 and 2005 fields and BSP

	alpha	ms	a	logL
2005-2004	1.0	0.54	39.1	- 457.3

a : estimated mean dispersal distance
logL : log-Likelihood

Maximum Likelihood estimated parameters from the seed flow model

Mature crops : best fitting seed dispersal kernel estimated by the present model
Pod popping : ballistic dispersal kernel (Colbach *et al*, 2001)
Secondary disp. : secondary seed dispersal kernel (Garnier *et al*, 2008)



Cumulative proportions of seeds dispersed from seed sources along roads

- 39.1 m of mean seed dispersal distance
- 2005 fields have no contribution on 2005 feral populations (*alpha* estimated to 1.0)
- 2004 fields by themselves explain 2005 ferals for 46%

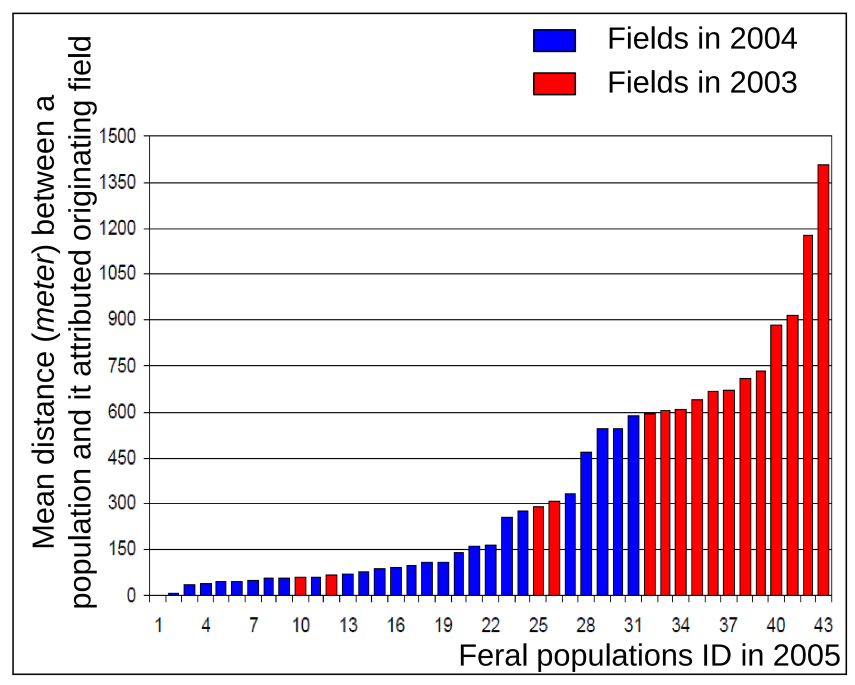
2005 Populations above 2002-2004 data

	ms	a	logL
2003-2004	0.23	403.8	- 430.2
2002-2004	0.28	374.6	- 433.4

Maximum Likelihood estimated parameters from the seed flow model

We extended the seed model without the contribution of the sown fields in 2005 but with 2002 and 2003 data in the area study :

- *ms* fraction decreases to 0.23 and 0.28
- mean dispersal distance was multiplied by 10 !



Mean distances between feral populations of the study area in 2005 and their origin fields in 2004 and 2003

Discussion

- Mean seed dispersal distance estimated by model 2005-2004 of 40 m is lesser than we can expect compared with secondary seed dispersal (vehicles re-entrainment) estimated to 20 m (Garnier *et al*, 2008).
- We worked in a sub-area of 7 km^2 and this choice explains the limitations of our model. We failed to detect 2005 fields effect and long-distance dispersal (by mowers, for example) because of the scale of the study and the fact that only 5 feral populations were present in 2004.
- We extended the seed model to 2003 and 2002 with the same construction type (exponential kernels, mean dispersal distance estimated for the years together …) :
  - Mean seed dispersal distance greatly improves to 400 m (versus 40 m) with 2003 data, which can be due to spatial configuration of the study area where 2004 fields were closer to relatives feral populations in 2005 than 2003 fields. As the distance estimated takes into account all year contributions together, it is still impossible to separate seed dispersal per year.
  - *ms* fraction decreases from 54% to 23% with 2003 data (16 fields of 2003 contribute to 2005 feral populations). *ms* fraction does not decrease with 2002 data (fields of 2002 do not contribute to 2005 feral populations).

Conclusions and prospects

- The seed dispersal model succeeds in estimating parameters for two years data and a sub-area of 7 km^2. But, 40 meters is shorter than we can expect for seed long distance dispersal and 400 meters is higher than expected.
- In order to have a more accurate estimation of long-term dispersal events, we project to take into account the whole region of Selommes (42 km^2) and to include all populations and fields of 2002 to 2005 (239 populations in 2005 versus 38 in the sub-area).
- The seed dispersal distance should be included in models estimating the escape of Genetically Modified Plants genes from fields. 40 meters is higher than ballistic abilities of dehiscent fruits, suggesting that dispersal is strongly linked with anthropogenic effects as vehicles traffic, mowing and harvesting.
- This summer, we will conduce an in-situ experimentation to mesure seed spillage from trunks during oilseed rape harvesting period in Selommes area.

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Further informations
http://www.ese.u-psud.fr/gmbioimpact/

Frugivores and Seed Dispersal — Montpellier, 13-18 June 2010