Accounting for spatially heterogeneous preferences while managing invasive species: a choice experiment

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Presentation Outline

The management of biological invasion

- Invasive species are causing tremendous impacts to ecosystems, economic activities and human welfare
- Definition: "A species occurring, as a result of human activities, beyond its accepted normal distribution and which threatens valued environmental, agricultural or other social resources by the damage it causes" (Australian Department of the Environment)

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- The number of reported invasive species is increasing at an accelerating yearly rate (Seebens and al. 2017)
- It is one of the main drivers of biodiversity loss
- Immediate management efforts are needed / Scarce financial resources

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- Measuring the costs and the benefits of managing the invasive species can guide decision-making
- Direct impacts / indirect impacts of the invasion $\rightarrow$ often non-market values
- Measuring the willingness to pay (WTP) of the concerned actors = approximation of the benefits of reducing the invasion

When preferences are spatially heterogeneous

- Impact of the invasion - and thus benefits of management - may be spatially heterogeneous
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- Impact of the invasion - and thus benefits of management - may be spatially heterogeneous
- As regularly pointed in the literature, spatial issues are a key feature in invasive species management (Hastings et al. 2005, Potapov and Lewis 2008)
- Some information is lost when estimating global or mean WTP
- A spatially explicit analysis is required to adequately set priorities of action

Discrete choice experiment for a spatial analysis?

- Discrete choice experiments (DCE): stated-preferences non-market valuation method
- DCEs have not been designed initially to assess spatially heterogeneous preferences but proves to be promising in this field

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- DCEs have not been designed initially to assess spatially heterogeneous preferences but proves to be promising in this field
- Each location / zone can be represented by an attribute
- Choice sets are composed of maps, associated with other attributes such as costs

Spatially explicit choice experiments

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- Horne et al 2005: use site-specific attributes to examine forest management in Finland
- Brower et al. 2010: spatially explicit preferences for water quality in a river basin in Southern Spain
- (Interis and Petrolia 2016: spatial analysis of ecosystem services values in the Gulf of Mexico, but using a different DCE for each site)

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- Brower et al. 2010: spatially explicit preferences for water quality in a river basin in Southern Spain
- (Interis and Petrolia 2016: spatial analysis of ecosystem services values in the Gulf of Mexico, but using a different DCE for each site)
- However, to our knowledge, there are no spatially explicit estimations of preferences with regards to invasive species, whereas spatial analysis is particularly advised in this field

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- Identify the factors explaining these spatially differentiated WTP

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- Identify the factors explaining these spatially differentiated WTP
- Implications for management strategies?
- First step for a cost-benefit analysis
- Our work is applied to an invasive amphibious plant, the Primrose willow, in a regional park in Western France

The invasion of the Primrose willow in France

- The site of our study is the Regional Park of Briere, west cost of France (*Loire-Atlantique*)
- Several touristic, recreational and agricultural activities: hiking, fishing, hunting, rowboats rides, pasture land for cows

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- Several touristic, recreational and agricultural activities: hiking, fishing, hunting, rowboats rides, pasture land for cows
- The Primrose willow (*Ludwigia grandiflora*) has been introduced from Latin America in 1991
- Explosive proliferation in the wetlands (aquatic plant)

Primrose willow invasion

source: Jean-Paul Juin

source: SBVB

source: Entreprise FOUGERE

The impact of the invasion

- Affects the biodiversity: native plants and fish populations
- Fishing and hunting activities are deteriorated
- Rowboats rides, appreciated by tourists, are made impossible in invaded canals
- The quality and diversity of the landscape is reduced
- The Primrose is toxic, making the invaded lands unsuitable for pasture, inducing losses for farmers (who also loose public aid for grasslands and their production label)
- Potentially increased flood risk

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- Limited budget $\rightarrow$ where to focus first?

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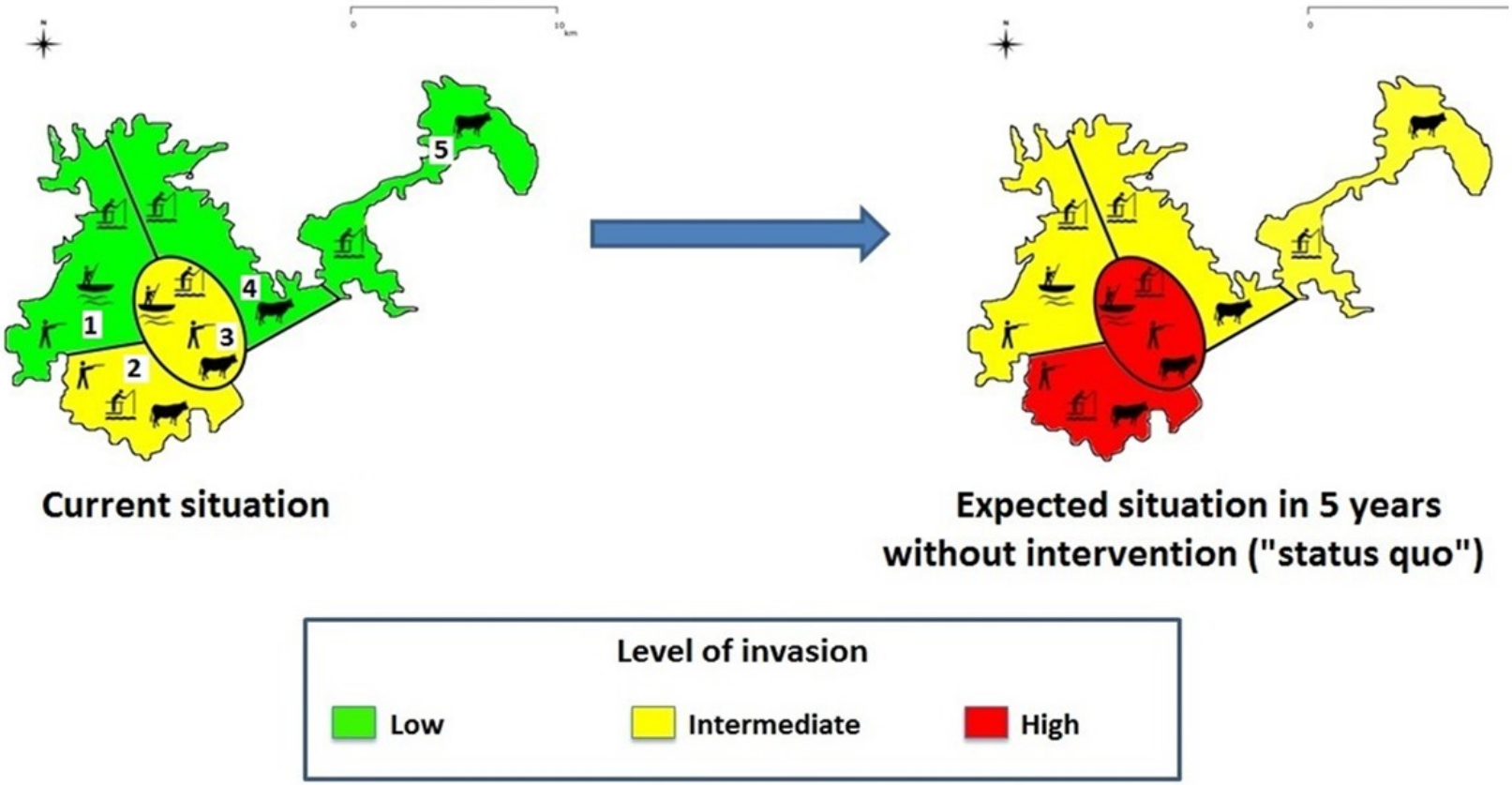
- Research grant 2016-2019 by the ONEMA in charge of the French national strategy on aquatic invasive species + ANR Green-Econ
- Three parts in the research project:
  1. **Estimation of the benefits derived from the management in the invaded zones**
  2. Estimation of costs of management in these zones
  3. Modeling the reproduction and dispersion dynamic of the species.

Actual invasion and forecast in five years



Definition of the attributes

- Respondents choose one alternative situation in five years between three, including the *Status Quo* (SQ, i.e. the situation in five years if nothing is done)

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- Definition of the attributes:
  - The five zones (defined after discussion with experts and pre-tests) correspond to one attribute each
  - One cost attribute: yearly tax increase (residential tax or tourist tax)

Definition of the levels

- Attributes' levels:
  - Five spatial attributes: low (green), intermediate (yellow), high (red) level of invasion
  - Cost attribute: 0 €/year (SQ), 5 €/year, 15 €/year, 30 €/year and 60 €/year
- Definition of the SQ

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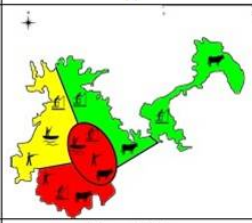
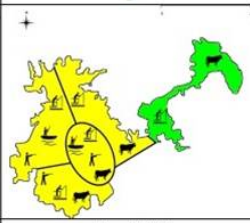
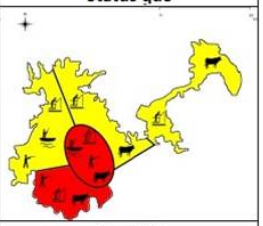
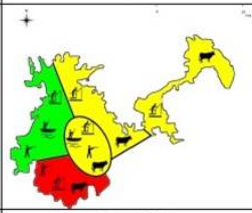
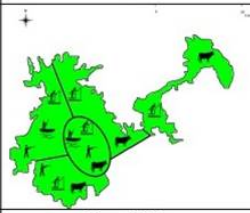
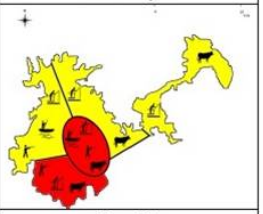
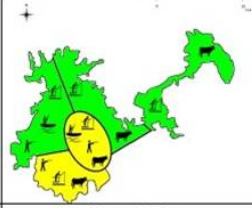
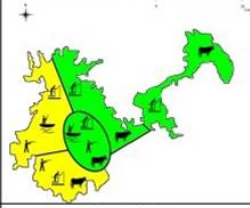
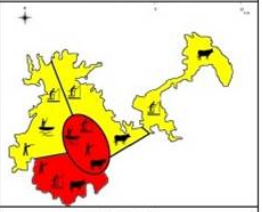
  - Five spatial attributes: low (green), intermediate (yellow), high (red) level of invasion
  - Cost attribute: 0 €/year (SQ), 5 €/year, 15 €/year, 30 €/year and 60 €/year
- Definition of the SQ
- Pre-test show that this number of attributes and levels is tractable for respondents: compared to a classical DCE, attributes are visually synthesized through a map reducing the cognitive burden

Examples of choice sets

Options	A	B	Status quo
Situation in 5 years			
Annual cost	Tax +15€	Tax +30€	Tax +0€
Your choice	○	○	○

Options	A	B	Status quo
Situation in 5 years			
Annual cost	Tax +5€	Tax +60€	Tax +0€
Your choice	○	○	○

Options	A	B	Status quo
Situation in 5 years			
Annual cost	Tax +60€	Tax +60€	Tax +0€
Your choice	○	○	○

The experimental design

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- Two constraints:
  1. The cost is always strictly positive in the non-SQ alternatives
  2. The level of invasion is never worst in the non-SQ alternatives compared to SQ
- We obtain 16 different choice sets, blocked into two groups: 8 choice sets presented to each respondent
- Ngene: RPL with normal distribution of coefficients, Halton(200)

Data collection

- Face-to-face interviews in the park during the summer 2016: 276 respondents, both tourists and residents
- Websurvey (still in progress) after information was released in local press and local amenities: 129 respondents

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- Websurvey (still in progress) after information was released in local press and local amenities: 129 respondents
- Four parts in the interview:
  1. A four-minutes video displaying general information on the invasion and its impacts on the various activities
  2. Preliminary questions (resident?, frequencey of visits in the park, reasons of visits, ...)
  3. Eight choice sets
  4. Questions on the degree of comprehension, reasons if SQ is always chosen, socio-economic characteristics...

Subjacent econometric theory

- Characteristic theory of value (Lancaster 1966) and Random utility theory (Mc Fadden 1973)
- The utility an individual i derives from the choice of an alternatrive a is composed of a deterministic and random component: $U_{ia} = V_{ia} + \varepsilon_{ia}$

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- Characteristic theory of value (Lancaster 1966) and Random utility theory (Mc Fadden 1973)
- The utility an individual i derives from the choice of an alternatrive a is composed of a deterministic and random component: $U_{ia} = V_{ia} + \varepsilon_{ia}$
- Linear distribution for the deterministic part
- Multinomial logit: unobserved components all follow a type I extreme-value distribution
- Mixed logit (or Random Parameter Logit) solves three drawbacks of the multinomial logit: preferences are not necessarily fixed across individuals, relaxed assumption of independence of irrelevant alternatives and unobserved components may be correlated (McFadden and Train 2000, Train 2009)

Econometric models

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- In the RPL, we assume random parameters follow a normal distribution
- We introduce an alternative specific constant (ASC) associated to the SQ situation
- First estimation without including interactions with socio-economic variables
- Second estimation including interactions with the place of residence in order to distinguish tourists/residents

The econometric model

$$
\begin{aligned}
U_{ia} \quad = \quad & \beta_{cost} cost_l + \gamma^l_{Z1} Z1_l + \gamma^l_{Z2} Z2_l + \gamma^l_{Z3} Z3_l \\
& + \gamma^l_{Z4} Z4_l + \gamma^l_{Z5} Z5_l + ASC + \beta^{SQ}_{LiveThere} LiveThere_i + \varepsilon_{ia}
\end{aligned}
$$

Formula for estimating the WTP

- We use the estimated parameters (iff statistically significant) to calculate the WTP associated with each attribute k and each level l as follows:

$$WTP_k^l = -\frac{\gamma_k^l}{\beta_{cost}}$$

- Interpreted as the WTP to change the situation of attribute k from the SQ level to level l, in euros
- As is common in the literature, β_{cost} is assumed to be constant across individuals (same marginal utility of income) (Hensher and Greene 2003)

Description of collected data

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- Sample of 312 individuals: out of the 405 initial respondents, we exclude 93 individuals who have not answered all questions
- Characteristics of the sample:
- Slightly more educated than national mean
- Slight over-representation of male
- Higher mean age compared to national statistics (53 instead of 41)
- Under-representation of farmers (data collection still in progress)

Respondents' characteristics

	Value or Percentage
Mean Age	52.86
Male	56.31%
Live in the Park	21%
Have visited the Park before	87%
Knew about the invasion before	47%

Respondents' characteristics (2) COMPLETER

Household yearly income	Percentage
<15,000 €	11%
15,001-25,000 €	32%
25,001-45,000 €	36%
> 45,001 €	21%

Coefficients' estimation

- We focus on the result of the RPL model which is more appropriate
- We focus on the results with interaction with the variable indicating if the respondent lives in the region

Coefficients' estimation

Table 4: Random Parameter Logit (normal distribution for random parameters)

	No Interaction				Interaction with					
					Liveln TheRegion			Liveln ThePark		
	Model (1)				Model (2)			Model (3)		
	Parameter Coeff. (SE)	SD Coeff. (SE)	WTP (€)	% with positive parameter	Parameter Coeff. (SE)	SD Coeff. (SE)	WTP (€)	Parameter Coeff. (SE)	SD Coeff. (SE)	WTP (€)
ASC	-1.231*** (0.440)	5.864*** (0.538)	-13.58	41.69%	-1.347*** (0.431)	5.900*** (0.516)	-14.26	-1.095 *** (0.416)	5.963 *** (0.524)	-11.70
Region 1										
Yellow	*Ref.*	*Ref.*	*Ref.*		*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Green	0.593*** (0.116)	0.854*** (0.148)	6.54	75.64%	0.814*** (0.154)	0.880*** (0.145)	8.62	0.810 *** (0.145)	0.891 *** (0.151)	8.65
X Local					-0.343** (0.225)		-3.64	-0.401** (0.244)		-4.29
Region 2										
Red	*Ref.*	*Ref.*	*Ref.*		*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Yellow	2.186*** (0.193)	0.750*** (0.148)	24.11	99.82%	1.609*** (0.220)	0.816*** (0.148)	17.67	1.860*** (0.211)	0.877*** (0.158)	19.87
X Local					1.175*** (0.248)		12.43	1.007*** (0.262)		10.76
Green	1.317*** (0.151)	0.154** (0.260)	14.53	100%	0.850*** (0.181)	0.035** (0.322)	9.00	1.035*** (0.171)	0.033*** (0.351)	11.06
X Local					0.991*** (0.235)		10.49	0.805*** (0.249)		8.60
Region 3										
Red	*Ref.*	*Ref.*	*Ref.*		*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Yellow	2.654*** (0.222)	1.852*** (0.199)	29.28	92.41%	1.955*** (0.260)	1.807*** (0.191)	20.70	2.289*** (0.254)	1.876*** (0.208)	24.46
X Local					1.587*** (0.240)		16.79	1.162*** (0.388)		12.42
Green	1.840*** (0.129)	0.088** (0.130)	20.29	100%	1.596*** (0.146)	0.007** (0.386)	16.89	1.735*** (0.146)	0.285*** (0.235)	18.54
X Local					0.539*** (0.202)		5.71	0.417* (0.223)		4.45
Region 4										
Yellow	*Ref.*	*Ref.*	*Ref.*	100%	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Green	0.608*** (0.105)	0.035** (0.170)	6.71		0.509*** (0.140)	0.002** (0.185)	5.38	0.461*** (0.128)	0.012*** (0.172)	4.92
X Local					0.214** (0.191)		2.27	0.439** (0.201)		4.69
Region 5										
Yellow	*Ref.*	*Ref.*	*Ref.*		*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*	*Ref.*
Green	0.457*** (0.114)	0.503*** (0.165)	5.04	81.82%	0.455*** (0.145)	0.565*** (0.165)	4.82	0.402*** (0.137)	0.568*** (0.173)	4.29
X Local					-0.026** (0.208)		-0.27	0.099** (0.225)		1.06
Tax	-0.091*** (0.006)				-0.094*** (0.007)			-0.094*** (0.007)		
Log L	-1,824.7812***				-1789.8577***			-1801.4387***		
#Obs.	7,488				7,488			7,488		
#Ind.	312				312			312		

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, ns Not significant

WTP Estimations

	WTP (€)
ASC	-11.70^{***}
Zone 1	
Yellow	*Ref.*
Green	8.65^{***}
Zone 2	
Red	*Ref.*
Yellow	11.06^{***}
Green	19.87^{***}
Zone 3	
Red	*Ref.*
Yellow	18.54^{***}
Green	24.46^{***}
Zone 4	
Yellow	*Ref.*
Green	4.92^{***}
Zone 5	
Yellow	*Ref.*
Green	4.29^{***}

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- Respondents are in favour of implementing management actions: they are willing to pay in average 12 euros per year to avoid the SQ situation in five years

A significant concern regarding the invasion (2)

- In Zone 1, respondents are in average willing to pay 9 euros per year to reduce the level of invasion from intermediate (yellow) to low (green)
- In Zone 2, respondents are in average willing to pay 11 euros per year to reduce the level of invasion from high (red) to intermediate (yellow) and 20 euros per year to reduce from high (red) to low (green)

A significant concern regarding the invasion (3)

- In Zone 3, respondents are in average willing to pay 19 euros per year to reduce the level of invasion from high (red) to intermediate (yellow) and 25 euros per year to reduce from high (red) to low (green)
- In Zone 4, respondents are in average willing to pay 5 euros per year to reduce the level of invasion from intermediate (yellow) to low (green)
- In Zone 5, respondents are in average willing to pay 4 euros per year to reduce the level of invasion from intermediate (yellow) to low (green)

A spatial heterogeneity of preferences

- For the same variation of invasion, we observe significant differences in WTP according to the concerned zone
- For example, respondents are willing to pay twice as much in Zone 1 (9 euros) as in Zone 5 (4 euros) for a same reduction of invasion
- According to our result, for a same change of invasion, respondents set priorities to Zone 1, followed by Zone 4 and last Zone 5. Similarly, Zone 3 seems more important to respondents' utility than Zone 2.

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- According to our result, for a same change of invasion, respondents set priorities to Zone 1, followed by Zone 4 and last Zone 5. Similarly, Zone 3 seems more important to respondents' utility than Zone 2.
- Reasons for this spatial differences?:
  - Recall that zones are similar in size
  - Activities (ex: rowboats rides between Z3 and Z2)?
  - Accessibility or proximity to place of residence (between Z5 and Z4)?

Distinction between residents' and tourists' answers

- When we look with more details into the role of the place of residence, and more specifically of living in the park, we note that this factor impacts the WTP for certain zones and not at all for others.
- Moreover, the spatial heterogeneity of preferences is increased with residents compared to tourists. A logical explanation is that residents know concretely the differences between zones and their proximity to their residence plays a role, contrarily to tourist who value the park as a whole.

Conclusion

- According to our results, preferences regarding the invasion of the Primrose willow in the Park of Briere, France, are spatially heterogeneous
- Our analysis has taken into account this spatial heterogeneity using a spatial DCE
- This approach allows to guide management decisions more precisely than when obtaining a global WTP

Conclusion

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- Our analysis has taken into account this spatial heterogeneity using a spatial DCE
- This approach allows to guide management decisions more precisely than when obtaining a global WTP
- This is only the first step to a wider cost-benefit analysis
- Priorities of action cannot be stipulated before estimations of differenciated costs across zones and analysis of the dynamic of spread of the species

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- Role of the interview mode (using dummies)
- Latent Class Model (in progress)
- Interactions with other socio-economic characteristics to understand better the spatial differences

Thank you for your attention!