SEVENTH FRAMEWORK PROGRAMME

INBIOS**O**IL

Innovative biological products for soil pest control

The economic and environmental benefits of biological control of Western Corn Rootworm *Diabrotica virgifera virgifera* and Wireworms *Agriotes spp.* in maize and potato for selected countries in Europe

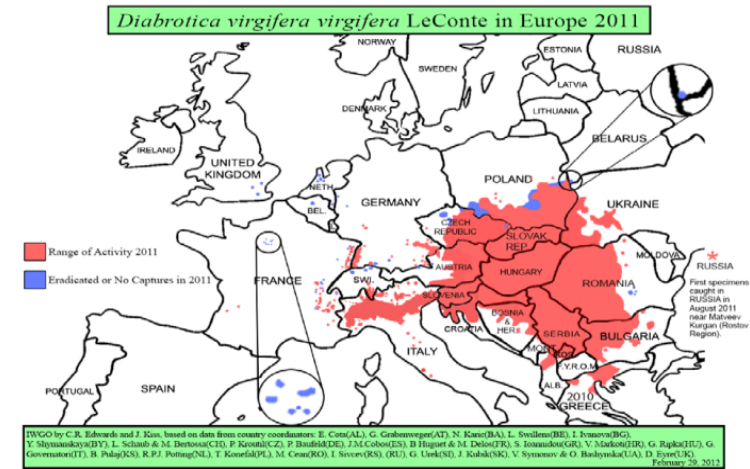## *Emmanuel Benjamin, Justus Wesseler*

AGENDA

- **Introduction**

- **Data**
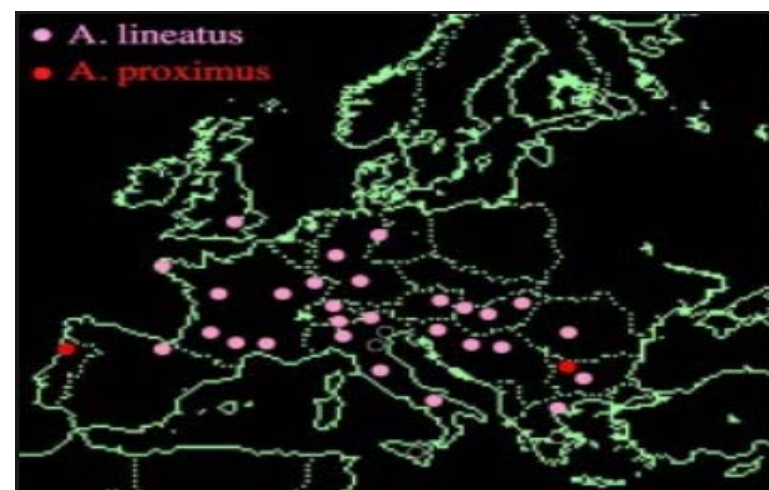
- **Methodology**
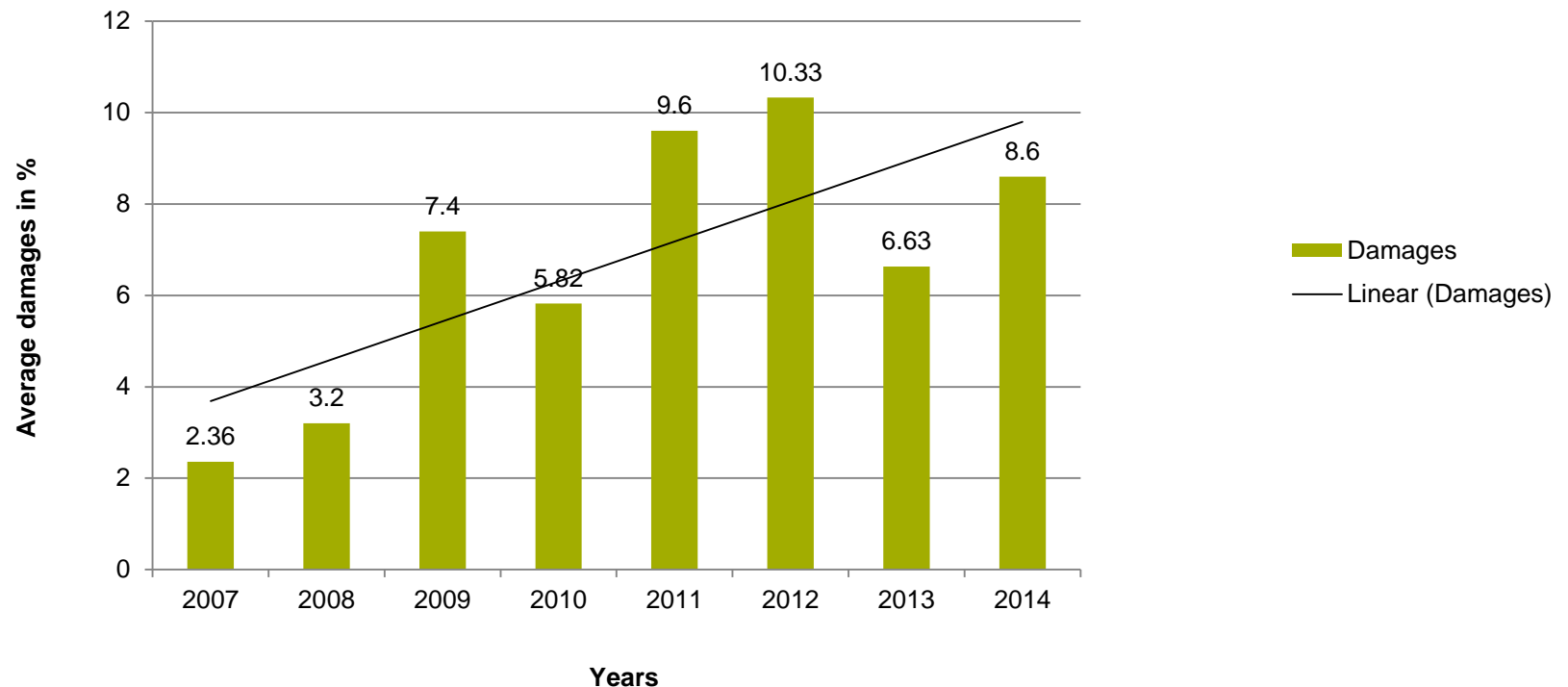
- **Results**

- **Conclusion**

Introduction

Western corn rootworm,
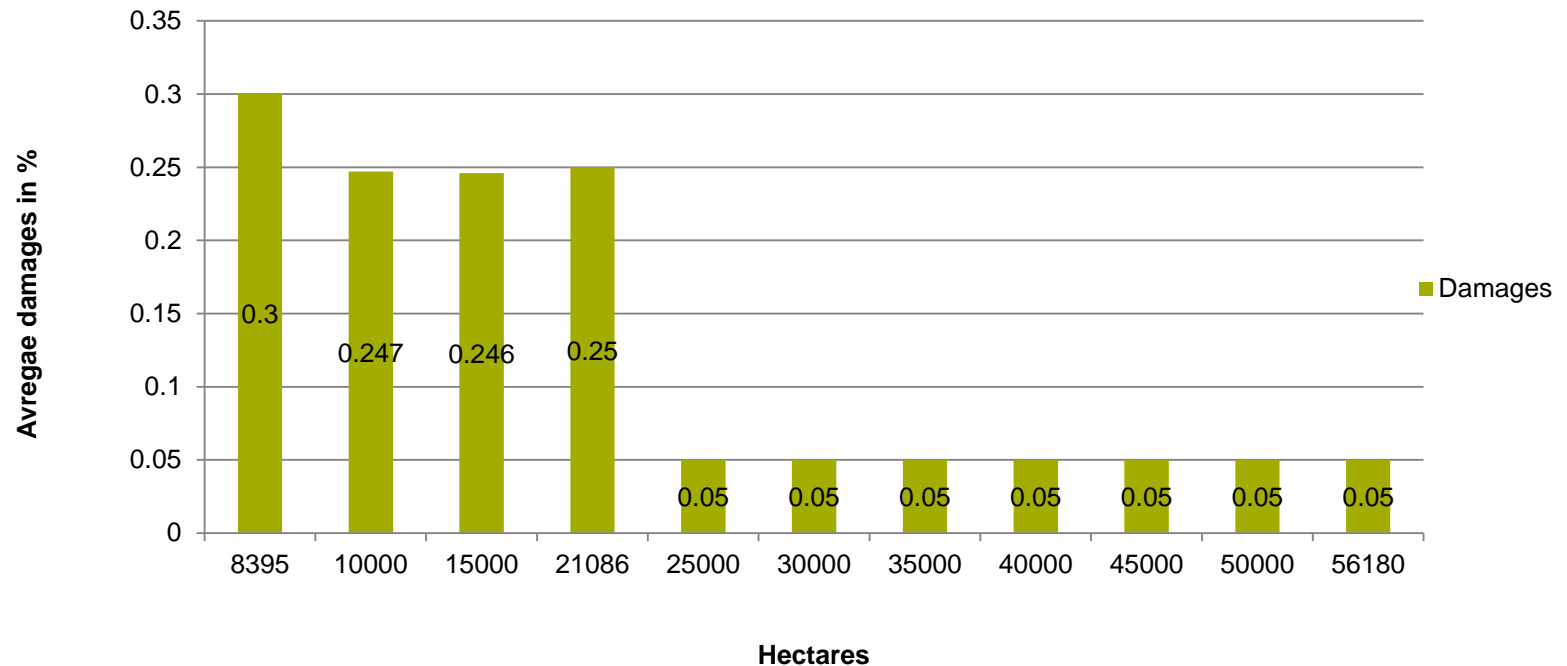*Diabrotica virgifera* virgifera

Wireworm,
Agriotes spp.

Wireworms damages in potatoes in Germany

Source: Ökoring, Bioland and Naturland, 2014

Wireworms damages in maize in Germany 2012

Source: authors using Deutsches Maiskomittee e.V. (DMK) **Drahtwurm im mais:Lösungsmoglichkeiten suchen**

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- Sustainable Use Directive (SUD) - 2009/128/EC
- Approval and renewal for new "active substances" - 1107/2009

Integrated Pest Management (IPM) Strategy

Synergy

Entomopathogenic Nematodes

Entomopathogenic Fungi

Semiochemical

INBIOSOIL
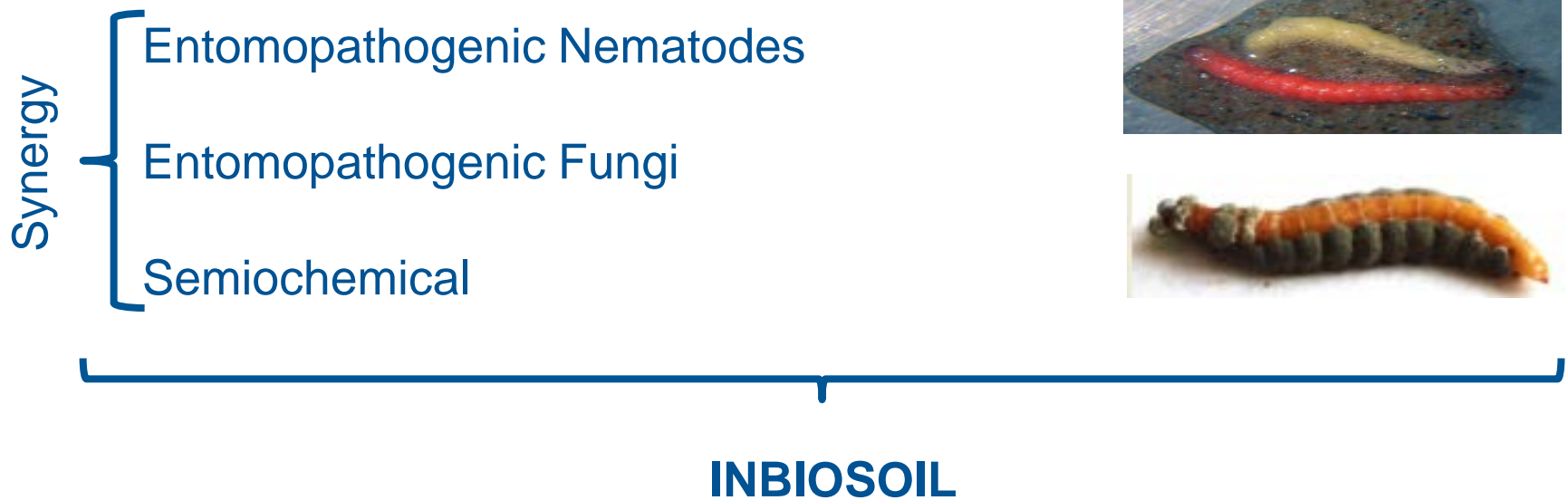
Critical factors

- **Proof of crop protection / population reduction**

WCR - nematodes and/or fungi

Jackson and Hesler, 1995; Kuhlmann and Burgt, 1998; Journey and Ostlie, 2000; Ulrich Kuhlmann et al. 2005; Vidal et al. 2005; Toepfer et al. 2008; Meissle et al., 2009; Toepfer et al. 2010; Strasser et al. 2014, Toepfer et al. 2014.

Wireworms - nematodes and/or fungi

Toba et al. 1983; Schalk et al., 1993; Kabaluk et al. 2005; Ericsson et al., 2007; Kabaluk and Ericsson, 2007; Ester and Huiting, 2007; Andrews et al. 2008; Ansari, 2009; Kleespies et al., 2013;

- **Proof of pesticide reductions in biological control**

Brown, 2008; USDA, 201; Gonzalez et al., 2008

Research Objective

- Crop protection ➜ leads to social incremental reversible benefits (SIRB)

- Pesticide reductions ➜ leads to social incremental Irreversible benefits (SIIB)

Quantification of *Total welfare* (SIRB + SIIB) till 2050

- Environmental benefit of pesticide reductions

Environmental Impact Quotient (EIQ) of pesticide reduction

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Field trails (Austria, Germany and Switzerland)
Farm production **(2013 – 2014)**
Efficacy of novel biopesticides

Bayerische Landesanstalt für Landwirtschaft (LFL)
Farm production **(2010 – 2015)**

EUROSTAT
Crop cultivated Area

Secondary literature
Price elasticity of demand and supply
Pest infestation and damages

Expert opinion (Extension services)

Field trials results using biological control for WCR in conventional maize cultivation (Germany and Austria) 2013

Variable cost			Germany						Austria					
			Biocontrol crop management		Conventionnal crop management				Biocontrol crop management			Conventionnal crop management		
Operational charges			€/ha	%		€/ha	%		€/ha	%			€/ha	%
Fertilizer			330	18		330	22		107	9			107	11
Irrigation			0	0		0	0		0	0			0	0
Hail insurance			34	2		34	2		63	5			63	7
Seeds			189	10		189	12		156	13			156	16
Plant protection			138	8		138	9		80	6			80	8
Drying			513	28		513	34		0	0			0	0
Maschinery			313	17		313	21		540	43			540	57
Labor wage			0	0		0	0		0	0			0	0
Extra charge for INBIOSOIL			300	17		0	0		300	24			0	0
total charges opérationnelles			1.816	100		1.516	100		1.246	100			946	100
difference to BIOCONTROL			0			-300			0				-300	
Product	Yield t/ha	Price (ton)	€/ha	%	Yield t/ha	Price (ton)	€/ha	%	Yield t/ha	Price (ton)	€/ha	%	Yield t/ha	Price (ton)	€/ha	%
Sales (product)	13.8	149	2056	100	10.9	148.6	1618	100	12.6	191	2407	100	10.0	191	1910	100
CAP subsidize (irrigated maize)			0	0			0	0			0	0			0	0
Revenue			2056	100			1618	100			2407	100			1910	100
difference to BIOCONTROL			0				-438				0				-146	
Gross margin			240				102				1.161				964	
difference to BIOCONTROL			0				-138				0				-197	

Field trails for *WCR* (Germany* / Austria):

Novel biopesticide *premium*: €300/ha

Yield effect = Income of treated field > €137/ha

Field trials results using biological control for Wireworms spp. in conventional potato cultivation (Switzerland and Germany) 2013

	Switzerland								Germany							
Variable cost	Biocontrol crop management				Conventionnal crop management				Biocontrol crop management				Conventionnal crop management			
Operational charges		€/ha	%			€/ha	%			€/ha	%			€/ha	%
Fertilizer		270	4			270	4			474	9			474	10
Irrigation		0	0			0	0			0	0			0	0
Hail insurance		555	8			555	9			106	2			106	2
Seeds		2.666	39			2.666	42			694	13			694	15
Plant protection (Fungicide etc.)		366	5			366	6			335	6			335	7
Maschinery		1.617	24			1.617	26			533	10			533	11
Storage		0	0			0	0			238	5			238	5
Fixed cost (labelling and quality control)		0	0			0	0			1.200	23			1.200	25
Leasing cost (land)		0	0			0	0			700	13			700	15
Interest Charges on loans		93	1			93	1			0	0			0	0
Labor wage (employee)		0	0			0	0			66	1			66	1
Labor wage		740	11			740	12			400	8			400	8
Extra charge for INBIOSOIL		500	7			0	0			500	10			0	0
Insecticides		0	0			0	0			0	0			0	0
total charges opérationnelles		6.808	100			6.308	100			5.246	100			4.746	100
difference to A - BIOCONTROL		0				-500				0				-500	
Product	Yield t/ha	Price (ton)	€/ha	%	Yield t/ha	Price (ton)	€/ha	%	Yield t/ha	Price (ton)	€/ha	%	Yield t/ha	Price (ton)	€/ha	%
Sale product	35.0	370	12950	72	29.8	370	11026	68	60.8	139	8451	100	48.0	139	6671	100
Subsidize			3733	21			3733	23			0	0			0	0
Sub-standard sales			1388	8			1388	9			0	0			0	0
Revenue			18072	100			16148	100			8451	100			6671	100
difference to A - BIOCONTROL			0				-1.924				0				-1.781	
Gross margin			11.264				9.840				3.205				1.925	
difference to A - BIOCONTROL			0				-1.424				0				-1.281	

Field trails for *Wireworms* (Switzerland / Germany):

Novel biopesticide *premium*: €500/ha

Yield effect = Income of treated field > €1275/ha

Partial Equilibrium Displacement Linear Model for Efficacious Biopesticide
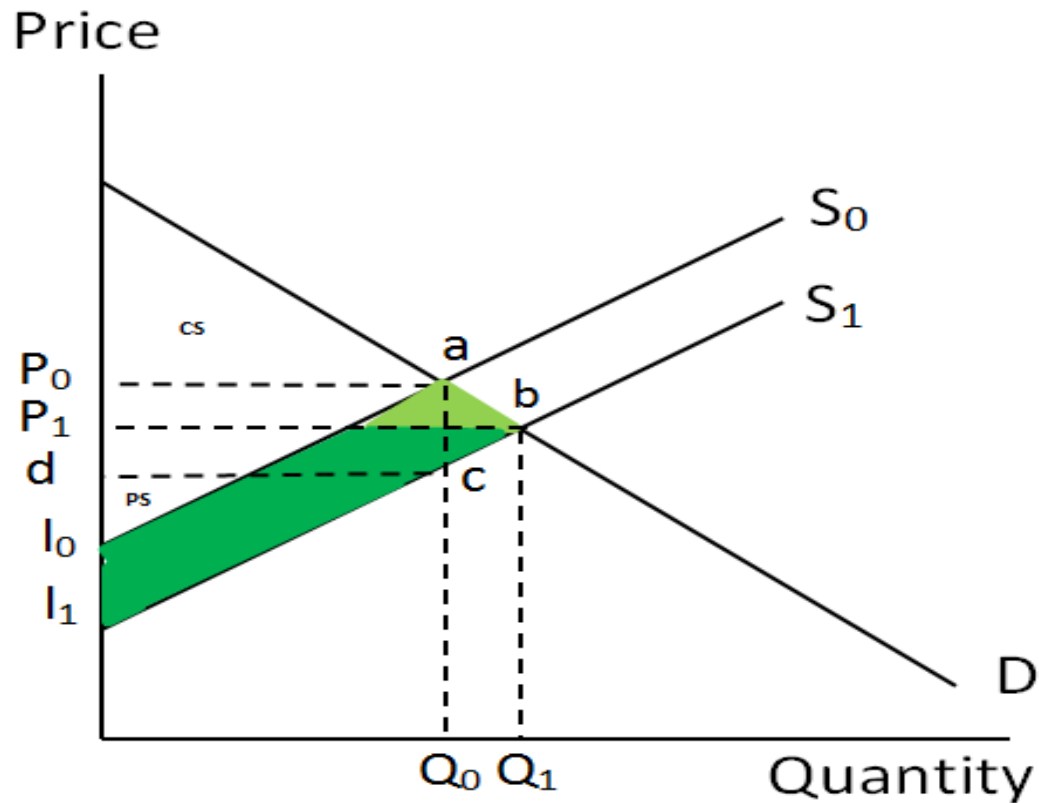
Pivot shift

$$K_{max} = \frac{\dfrac{VC_c}{y_c} - \dfrac{VC_{biopest}}{y_{biopest}}}{\dfrac{VC_c}{y_c}}$$

$K_{max} - Maximum\ pivot\ shift$

$VC_c - Variable\ cost\ conventional\ control$

$y_c - Yield\ conventional\ control$

$VC_{biopest} - Variable\ cost\ biopesticide\ control$

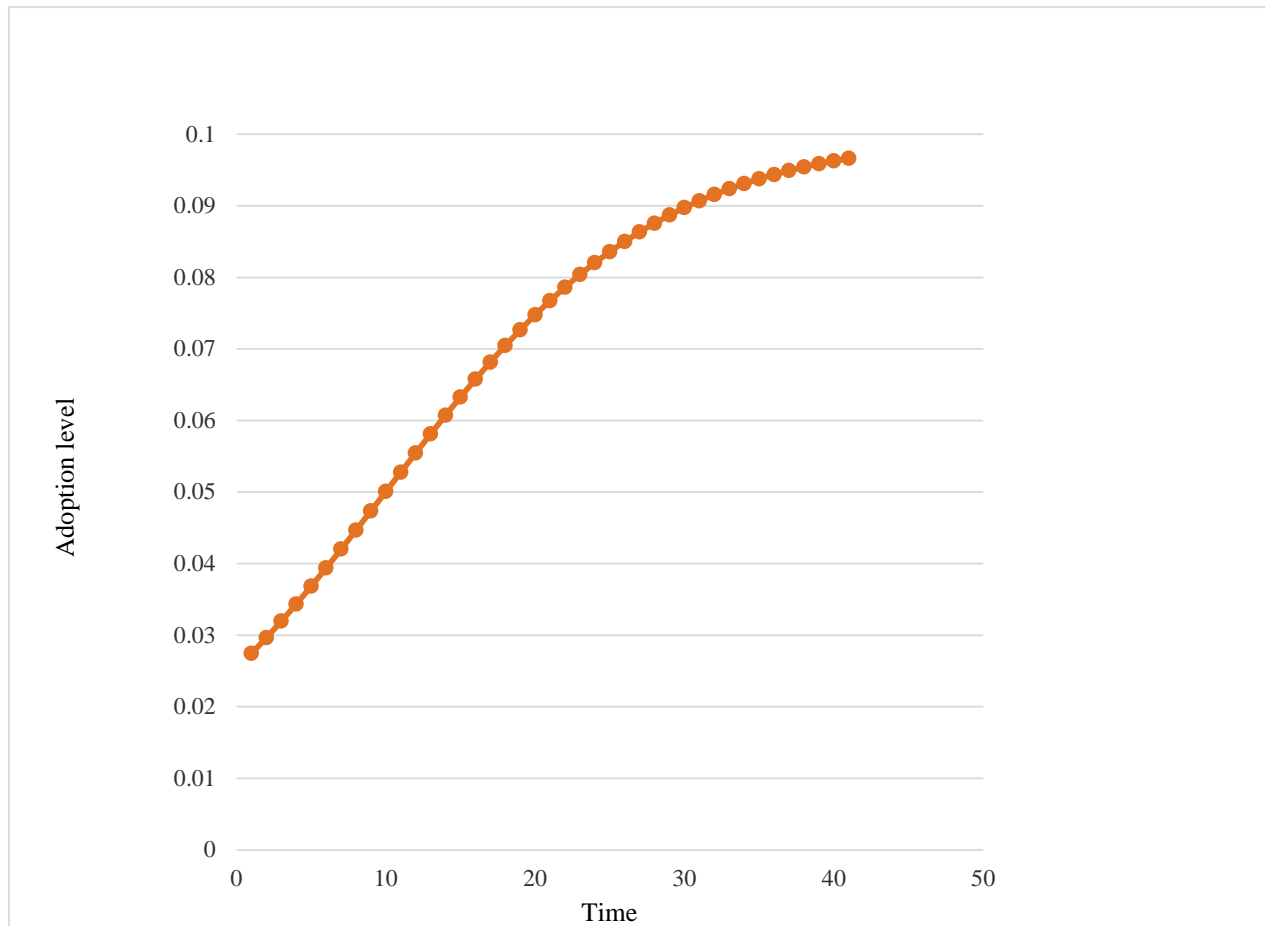$y_c - Yield\ biopesticide\ control$

Adoption rate

$$\theta(t) = \frac{\theta_{max}}{(1 + e^{-(a+bt)})}$$

$\theta(t) - Adoption\ at\ time\ (t)$
$\theta_{max} - Maximum\ adoption$

Adoption curve of biopesticide in organic cultivation in the EU-27 (proxy for potato cultivation)

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Social Incremental Irreversible Benefit (SIIB)

$$AI * AI \text{ cost} * A$$

AI = Active ingredient

AI cost = External cost of pesticide AI (€0.79 - € 19/kg)
(Demont et al. 2004 / Lens 2004)

A = Total area of cultivation

Environmental Benefit − Environmental Impact Quotient (EIQ)

Farmer component   *Consumer component*   *Ecological component*

$$EIQ = \frac{\left(C[(DT*5) + (DT*P)] + \left(C\left[\frac{(S+P)}{2}\right] * SY\right) + (L) + (F*R) + \left(D\left[\frac{(S+P)}{2}\right] * 3\right) + (Z*P*3) + (B*P*5)\right)}{3}$$

C = chronic toxicity

DT = dermal toxicity

P = plant surface residues half-life

S = soil residues half-life

SY = systemicity

L = leaching potential

F = fish toxicity

R = surface loss potential

D = bird toxicity

Z = bee toxicity

B = beneficial arthropod toxicity

Results

Total welfare of the adoption of biological control (max. 30%) against WCR in Maize cultivation in (€)

	France		Italy		Spain		Germany		Austria		Romania	
Year	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB
2010 – 2050 (SIIB €0.79/kg)	118,312,143	1,117,639	75,992,669	703,226	31,838,442	268,211	34,741,876	295,153	18,398,088	133,059	81,164,545	1,510,693
Total welfare Benefit (SIRB + SIIB)	**364,475,745**											
	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB
2010 – 2050 (SIIB €19/kg)	118,312,143	26,879,922	75,992,669	16,913,026	31,838,442	6,450,649	34,741,876	7,098,607	18,398,088	3,200,152	81,164,545	36,333,110
Total welfare Benefit (SIRB + SIIB)	**457,323,233**											

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Total welfare of the adoption of biological control (max. 10%) against Wireworms in potato cultivation in (€)

	France		Italy		Spain		Germany		Austria		Romania	
Year	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB
2010 – 2050 (SIIB €0.79/kg)	659,750,895	32,050	231,925,450	12,730	226,225,607	15,791	623,796,751	51,901	45,181,220	4,488	409,829,010	49,392
Total welfare Benefit (SIRB + SIIB)	**2,196,875,289**											
	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB	SIRB	SIIB
2010 – 2050 (SIIB €19/kg)	659,750,895	770,833	231,925,450	306,175	226,225,607	379,774	623,796,751	1,248,250	45,181,220	107,946	409,829,010	1,187,899
Total welfare Benefit (SIRB + SIIB)	**2,200,709,814**											

Environmental Benefit − Environmental Impact Quotient (EIQ)

Name	Farmer; Consumer; Ecology EIQ Values	Farm worker component	Consumer component	Ecological component
Tefluthrin (FORCE ®)	25.33	6	2	68
Cypermethrin (Belem ®)	36.35	13.80	5.90	89.35

Research Department Agricultural Economics (RDA)
Group of Agriculture and Food Economics

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- WCR and Wireworms causing *havoc* in maize and potato cultivation

- Efficacious biological control in IPM (strategy) has *matured*
  - (*A lot still **depends** on ………*)

- Innovation and research on improving efficacy is *promising*

- **Total welfare benefits *Constant Elasticity Model* (2010 – 2050):**

Maize ca. *€410 million* (France, Italy, Spain, Germany, Austria, and Romania)

Potato ca. *€2 billion* (France, Italy, Spain, Germany, Austria, and Romania)

- *EIQ* for conventional control - FORCE ® and Belem ®:

Ecological Component - *High*

Thanks for your Attention

Comments? Questions?