A methodological framework for the valuation of natural predators

A case study of ecological - economic modeling in low strain pear production in Belgium

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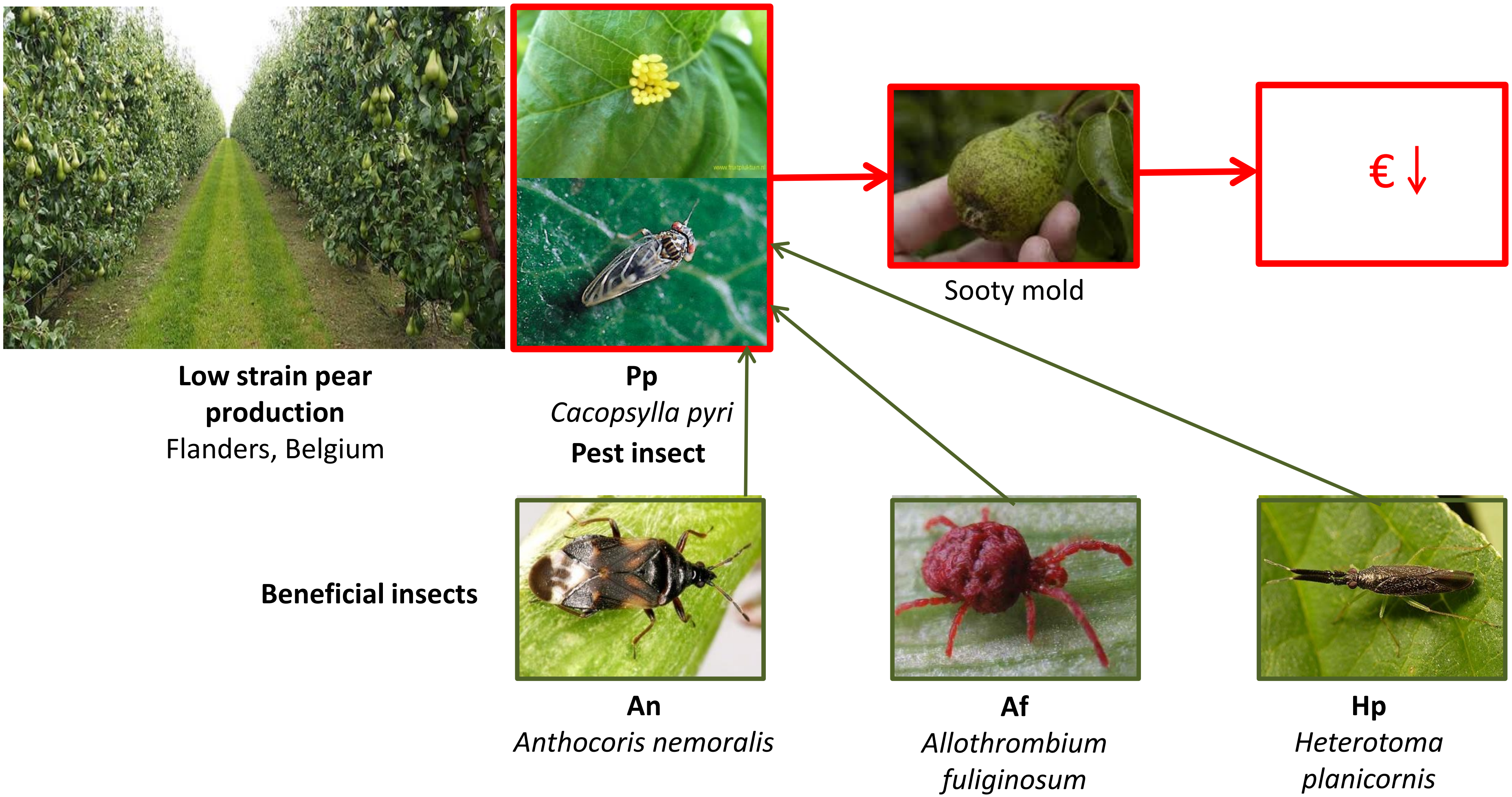
Agroecosystem low strain pear production, Flanders (BE)

Ecosystem-based approach to biodiversity valuation taking into account the functional role of species within the ecosystem



1. Research objectives

(i) to quantify the link between the loss of species and the provisioning of ecosystem services (biological pest control)

(ii) to quantify the economic losses which can be attributed to a reduction of natural predators

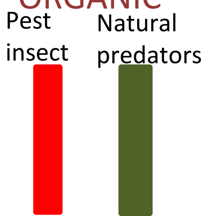
(iii) To develop a general methodological framework for the valuation of non-marketable species based on their ecological role within the ecosystem (ecosystem-based approach for the valuation of biodiversity)

Ecosystem-based approach to biodiversity valuation taking into account the functional role of species within the ecosystem

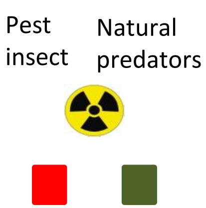
1. Biodiversity loss function

Modeling population dynamics for 2 management scenarios

ORGANIC



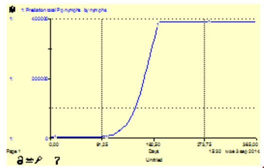
IPM



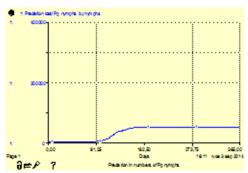
2. Analysis of ESS losses

Biological pest control: # pp removed by np

ORGANIC



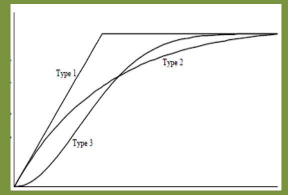
IPM



3. Ecological - economic linking functions

a. Damage control framework

Yield loss



Pest population density

b. External costs framework

Pesticide use

↓

External costs

4. Direct and indirect costs

Extended Economic Injury Level (EIL) and Cost Benefit Analysis

ORGANIC

$p(Y)$

μZ

IPM

$p(Y)$

μZ

$EC(X)$

ωX

m

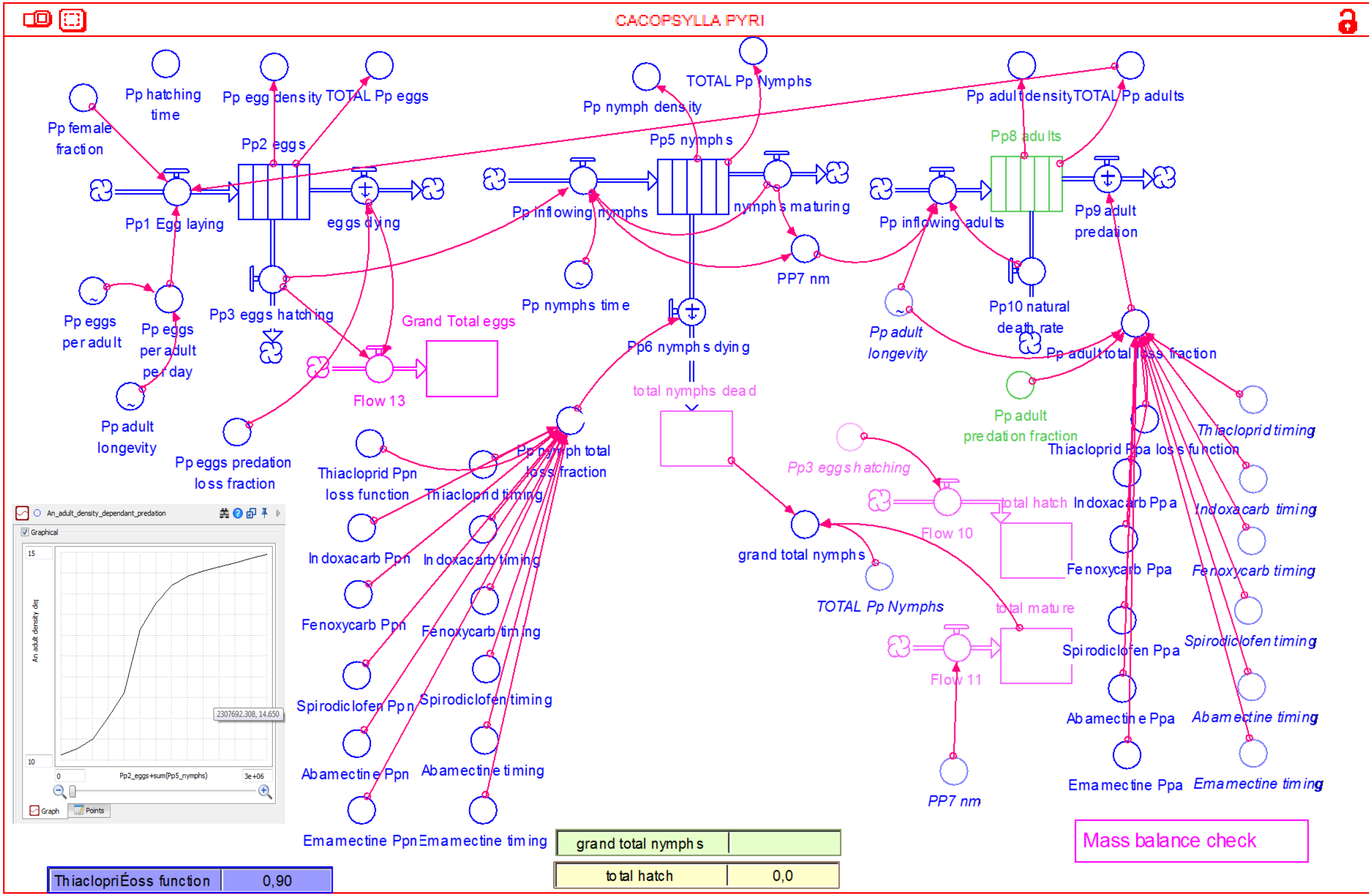
5. Valuation of natural predators

= CONTRIBUTION OF NATURAL PREDATORS TO THE REDUCTION OF DIRECT AND INDIRECT COSTS OF PEAR PRODUCTION

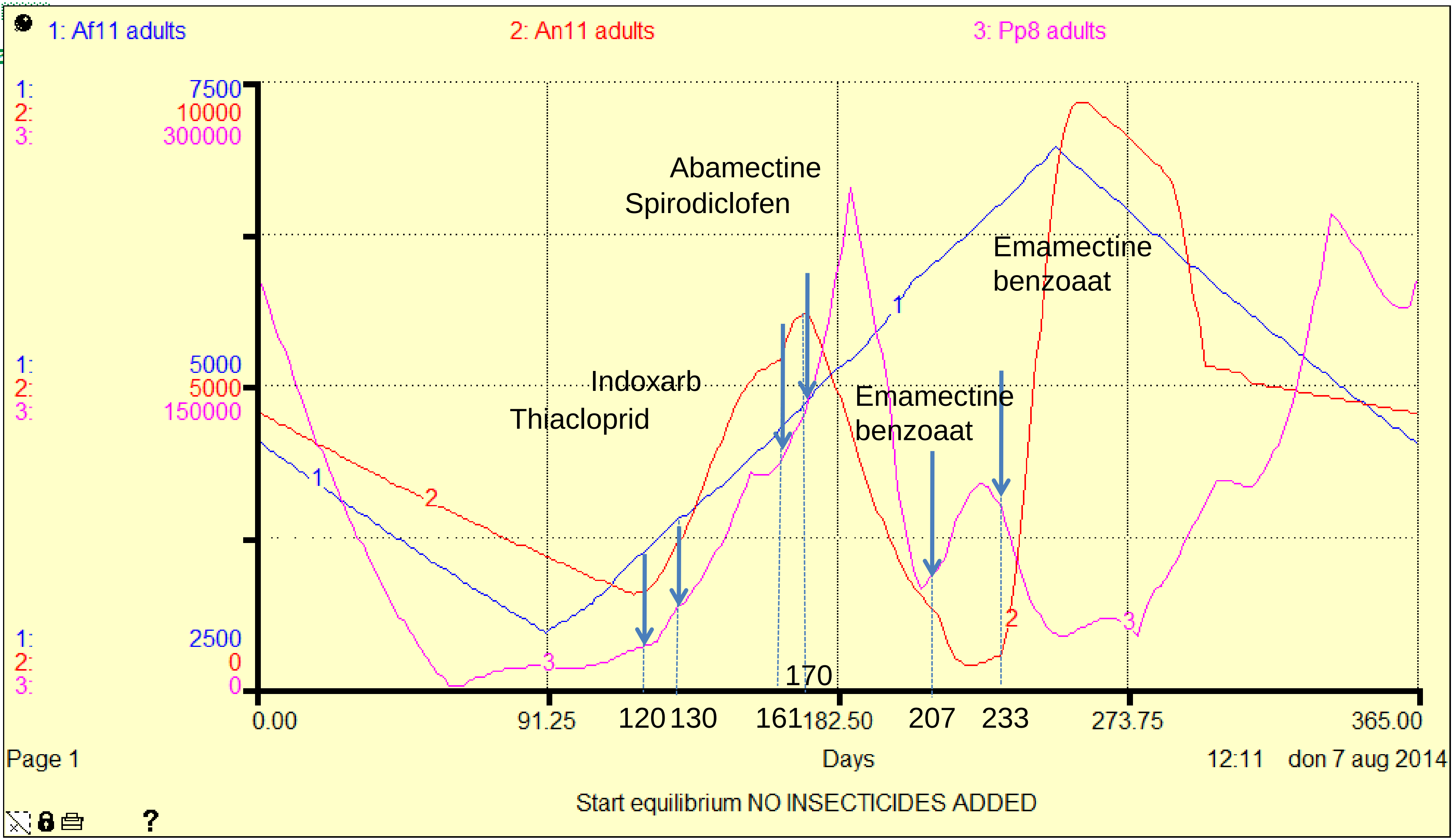
ECOLOGICAL MODEL

ECONOMIC MODEL

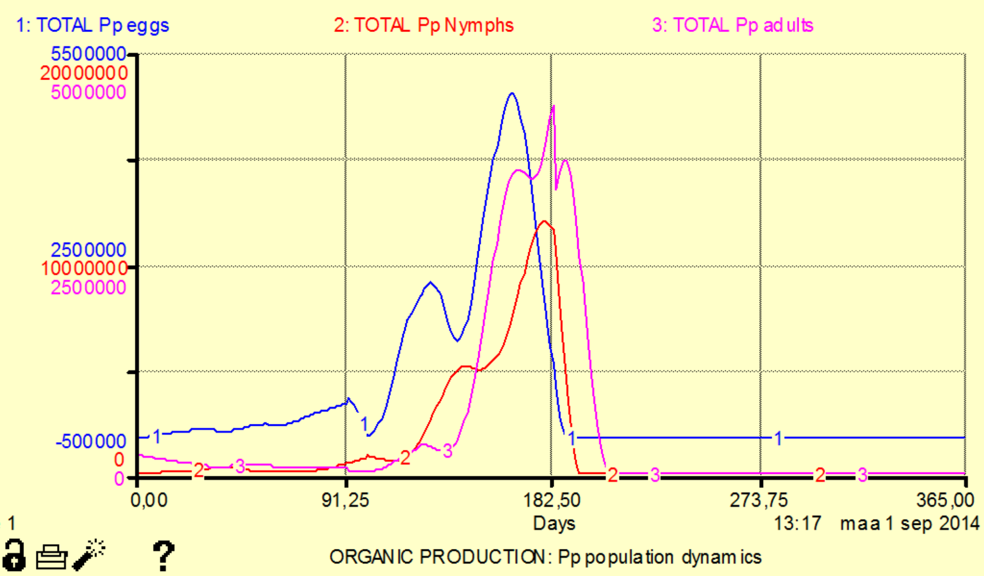
3. Modeling population dynamics (1): prey model Pp (stella)

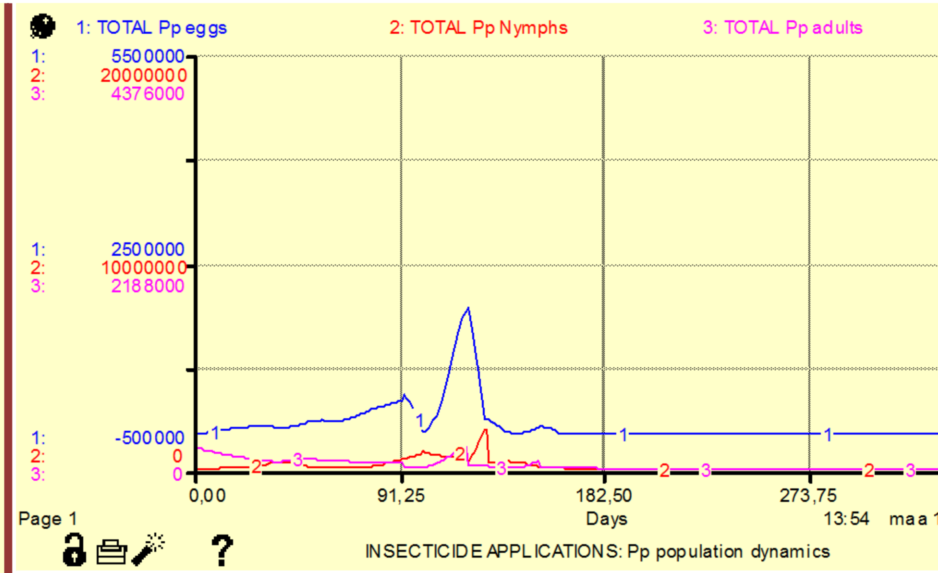


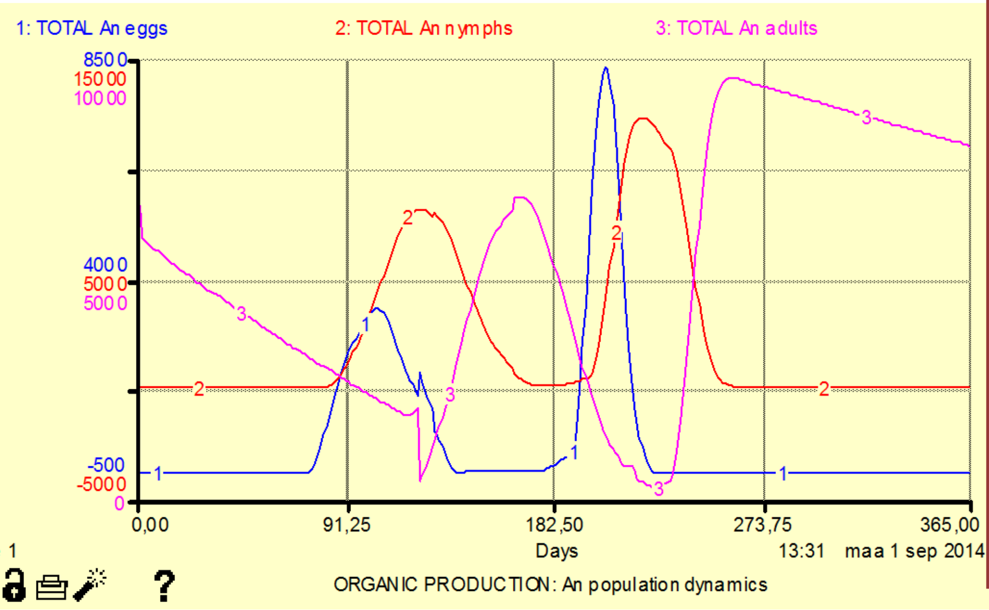
3. Modeling population dynamics (2): insecticide applications

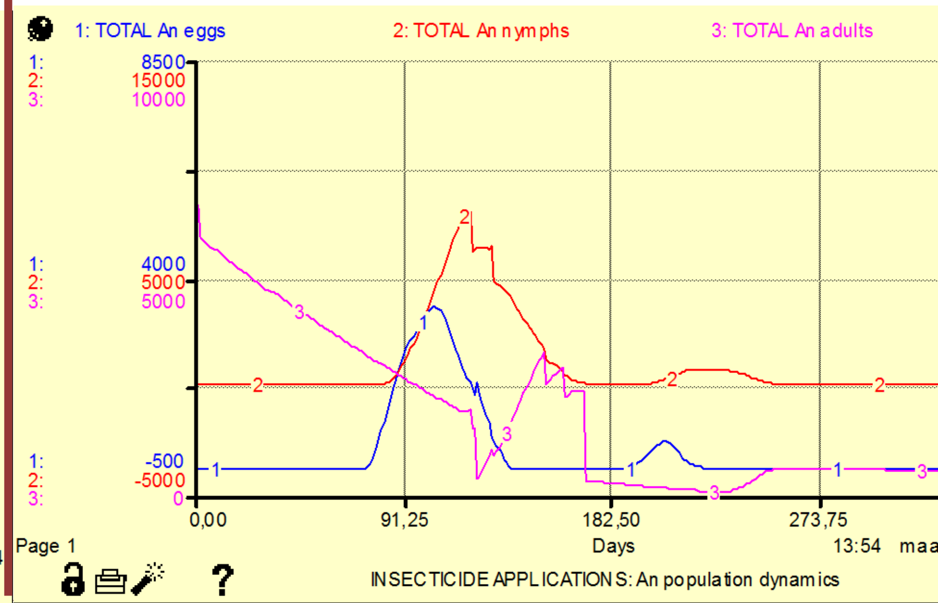


4. Biodiversity loss function (1): changes in species abundance

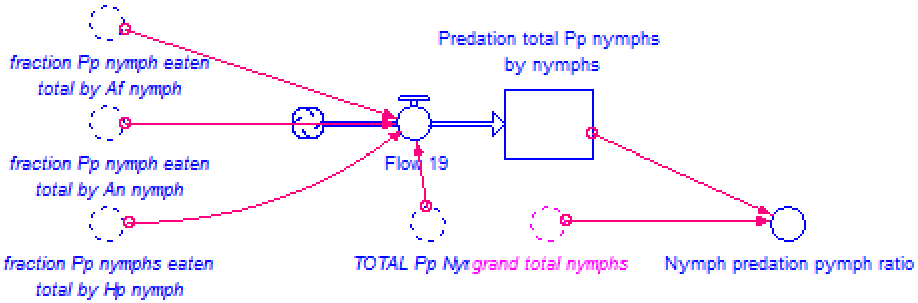








4. Biodiversity loss function(2): changes in predator abundance



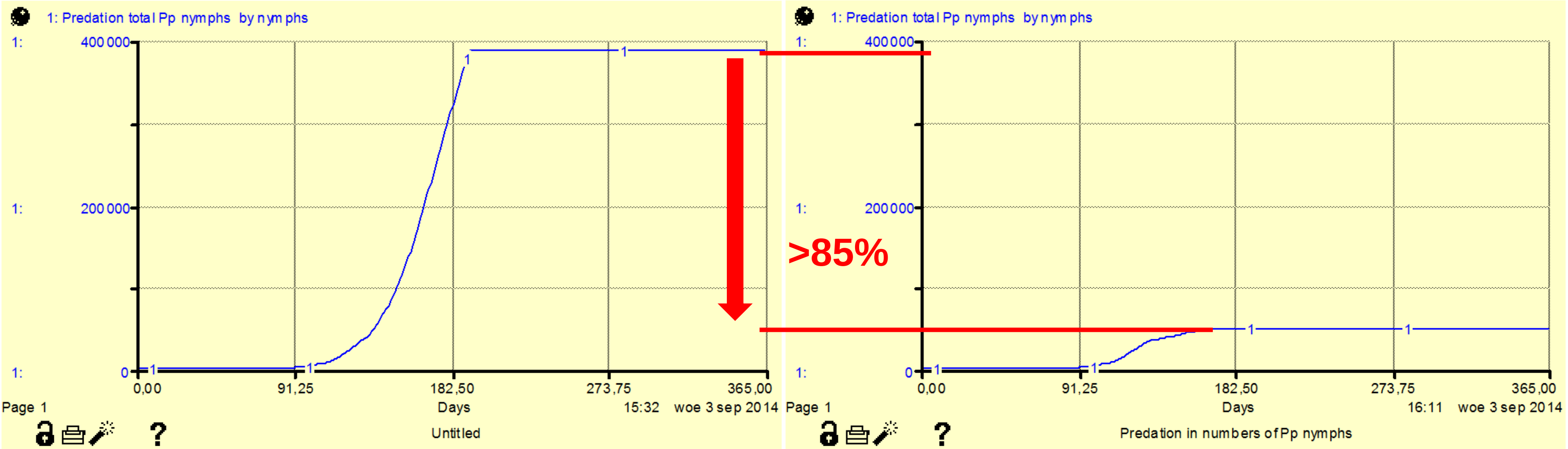
Grand total Af nymphs	4.808,4	Grand total Af nymphs	3.621,5
Grand total An nymphs	27.020,5	Grand total An nymphs	13.016,4
Grand total Hp nymphs	1.808,9	Grand total Hp nymphs	1.472,2

Absolute number	Loss fraction	Reference scenario (organic pear production)	Alternative scenario (IPM)	Δ
1. *Allothrombium fuliginosum*	Safety standard (<25% loss fraction)	100% 4808.4 #	75% 3621.5 #	**25%** ⬇
2. *Anthocoris nemoralis*	Safety standard (<25% loss fraction)	100% 27020.5 #	48% 13016.4 #	**52%** ⬇
3. *Heterotoma planicornis*	Safety standard (<25% loss fraction)	100% 1808.9 #	81% 1472.2 #	**19%** ⬇

5. Analysis of ESS: loss of biological pest control

	Reference scenario (organic pear production) # Pp nymphs	Alternative scenario (IPM) # Pp nymphs	Loss of biological pest control potential
1. Total predation	388.724	47.744	**87.72%**
2. Sensitivity analysis [0.01-0.25] death rate		[min 43.727, max 48.552]	**[87.5%, 87.72%]**

87.72% loss in potential biological pest control
(Inspite safety level <25% loss fraction for beneficial insects)



Ecosystem-based approach to biodiversity valuation taking into account the functional role of species within the ecosystem

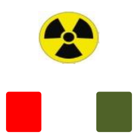
1. Biodiversity loss function

Modeling population dynamics for 2 management scenarios

ORGANIC

IPM

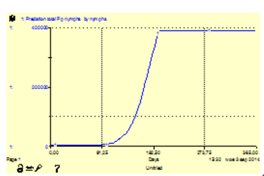
Pest insect | Natural predators



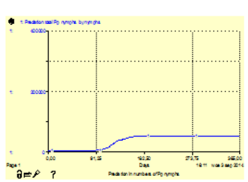
2. Analysis of ESS losses

Biological pest control: # pp removed by np

ORGANIC



IPM

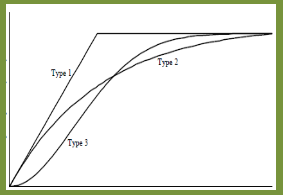


ECOLOGICAL MODEL

3. Ecological - economic linking functions

a. Damage control framework

Yield loss



Pest population density

b. External costs framework

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Extended Economic Injury Level (EIL) and Cost Benefit Analysis

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5. Valuation of natural predators

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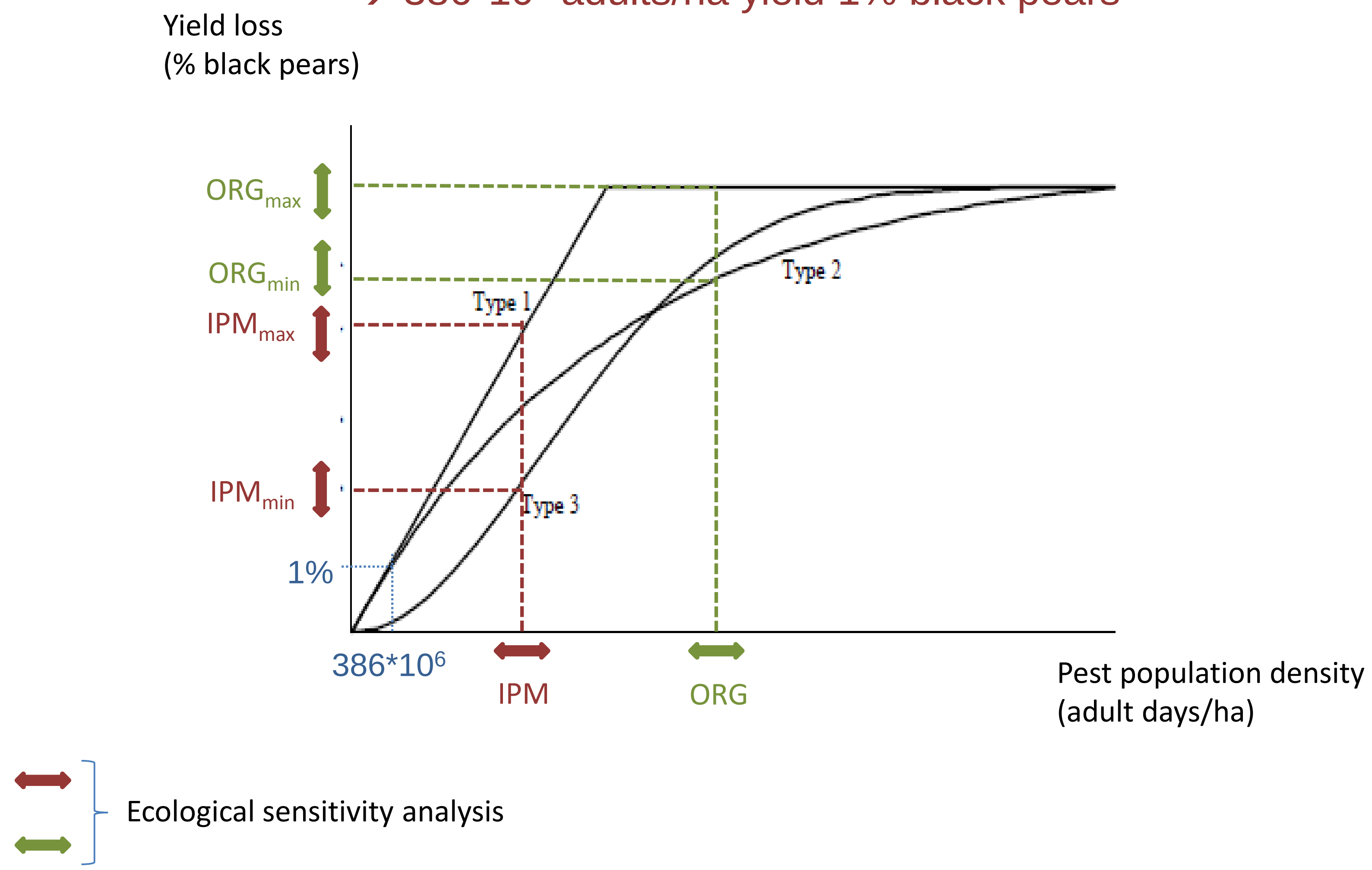
ECONOMIC MODEL

6. Ecological economic linking function 1

→1000 PP adults yield ‘detectable damage’
→ $386*10^6$ adults/ha yield 1% black pears



7. The economics of pest control (1): theoretical framework

$$Y = g(Z)[1 - D(N_1)]. \quad (1)$$

$$N_1 = h(N_0, X, A). \quad (2)$$

$$\underset{\{Z,X,A\}}{\text{Max}}\; pg(Z)[1 - D(h(N_0, X, A))] - uZ - vA - wX \quad (3)$$

Preventive applications:

$$\underset{\{X\}}{\text{Max}} \prod_p = pg(Z) \int_{N_1}^{N_2} [1 - D(\overline{N}, X)]\, \psi(\overline{N}) dN - wX$$

Responsive applications:

$$Max \prod_p = pg(Z) \int_{N1}^{N2} [1 - D(N, X(N))] \varphi(N) dN - \omega \int_{N1}^{N2} X(N)\, \varphi(N) dN - \mu Z(management) - m$$

$\sum (direct\ costs)$

Lichtenberg, E., and D. Zilberman. 1986a. "The Econometrics of Damage Control: Why Specification Matters." *American Journal of Agricultural Economics* ***68: 261–273.***

7. The economics of pest control (2): theoretical framework

Responsive applications:

$$Max \prod_{p} = pg(Z) \int_{N1}^{N2} [1 - D(N, X(N))] \varphi(N) dN - \omega \int_{N1}^{N2} X(N) \varphi(N) dN - \mu Z(management) - m$$

Natural predators:

$$N_1 = h(N_0, X, A)$$

$$N_1 = h(N_0, X, K)$$

Externalities:

$$\vartheta \rho \int_{X1}^{X2} C_{ext} \varphi(N) dN \quad with\ C_{ext} = f[X(N), EIQ(X), TC(X)]$$

$$Max \prod_{p} = pg(Z) \int_{N1}^{N2} [1 - D(N, X(N), P(X))] \varphi(N) dN - \omega \int_{N1}^{N2} X(N) \varphi(N) dN$$
$$- \vartheta \rho \int_{X1}^{X2} C_{ext} \varphi(N) dN - \mu Z(management) - m$$

$\sum$ (direct costs, indirect costs)

8. Empirical framework (1): direct costs analysis Aramis (@Risk)

ECONOMISCHE ANALYSE PEER - DOYENNE

Deelnemer: 43498 Periode: 01/06/12-31/05/13 80005

Opbrengst (Gem.ouderdom: 20 j, bomen/ha: 1.971)	Totaal 400 kg	per ha 0,42 ha	per ton (952 kg/ha)
Verkoop			
-consumptiefruit(400 kg)	400,00	952,38	1.000,00
-schilappel(0 kg)			
-rebut(0 kg)			
Premies en diversen	92,97	221,36	232,42
Intern			
-verbruik hoofdprodukt			
-verbruik bijprodukt			
-omzet/aanwas/voorraadverschil beplantingen			
Totale opbrengst	**492,97**	**1.173,74**	**1.232,42**
Variabele kosten			
-zaaigoed			
-meststoffen	125,24	298,19	313,10
-gewasbescherming	571,91	1.361,69	1.429,77
-seizoenslonen en loonwerk	579,36	1.379,44	1.448,41
-onderhoudskosten	275,84	656,75	689,59
-verpakkingsmateriaal	2,67	6,36	6,67
-bewaarkosten			
-andere leveringskosten	12,99	30,94	32,48
-diversen	225,10	535,96	562,76
->Adm. kost seizoenarbeid(119 euro) / Niet gespecifieerd(96 euro,...)			

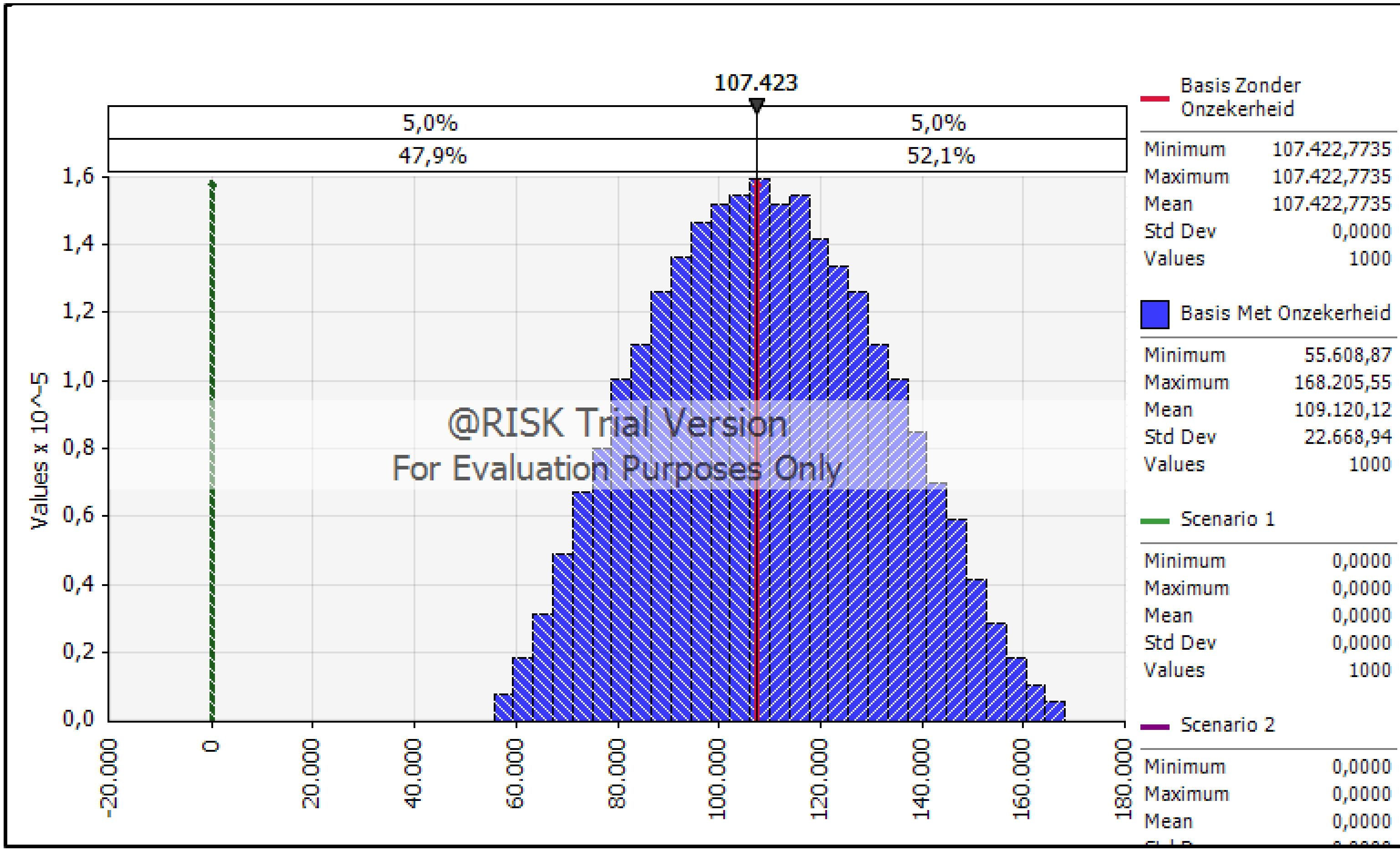
$Y(IPM) > Y(ORG)$

$p(IPM) < p(ORG)$

$\omega X(IPM) > \omega X(ORG)$

$\mu Z(IPM) < \mu Z(ORG)$

8. Empirical framework (2): direct costs analysis Aramis (@Risk)



➡ Difference in direct costs for the two scenarios $\sum(direct\ costs_{IPM}) \Leftrightarrow \sum(direct\ costs_{ORG})$

➡ Calculate the contribution of natural predators to a reduction in direct costs

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9. Empirical framework (3): indirect costs analysis

i. Public health impacts
ii. Groundwater contamination
iii. Fishery losses
iv. Honeybee and pollination losses
v. Crop losses

Human health effects from pesticides	Total costs ($)
Cost of hospitalized poisonings	
5000[1] × 3 days at $2000 per day	30 000 000
Cost of outpatient-treated poisonings	
30 000[2] × $1000[3]	30 000 000
Lost work due to poisonings	
5000[1] workers × 5 days × $80	2 000 000
Pesticide cancers	
10 000[2] × $100 000/case	1 000 000 000
Cost of fatalities	
45 accidental fatalities[1] × $3.7 million	166 500 000
TOTAL	1 228 500 000

[1] Estimated.
[2] See text for details.
[3] Includes hospitalization, foregone earnings, and transportation.

$$\sum_{i=1}^{n}(X_1, X_2, \dots X_n)$$

(Pimentel, 2005)

9. Empirical framework (4): indirect costs linking function

Ecological economic linking function 2: pesticide use – external costs

EIQ

Environmental Impact Quotient

1. Farm workers (applicators & pickers)
2. Consumers (ground water leaching & food consumption)
3. Environment (aquatic life, bees, birds)

$$\sum_{i=1}^{k}(X_i, X_j X_k)$$

→

PEA

Pesticide Environmental Accounting Tool

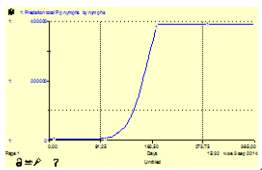
$$\mathrm{TEC_p} = \mathrm{Rate_p} * \frac{\mathrm{Active_p}}{100} * \sum_{c=1}^{8}\left[\mathrm{EC_c} * \mathrm{F_c} * (\mathrm{F_{agemp}} | c = 1{,}2)\right] * \mathrm{F_{gdppc}} * \mathrm{F_{adj}}$$

10. Valuation of natural predators

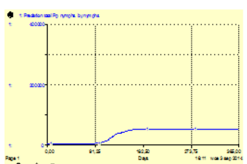


Loss of biological pest control

ORGANIC

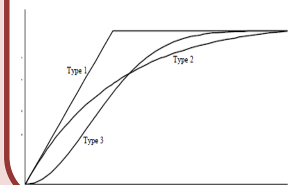


IPM

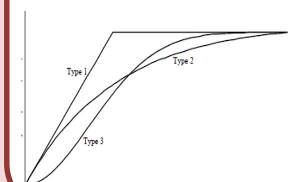


Yield loss

ORGANIC

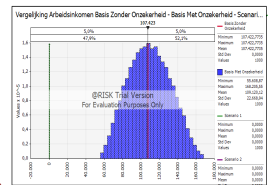


IPM

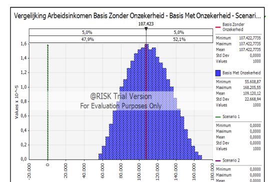


Direct Costs

ORGANIC



IPM



Indirect Costs

ORGANIC

PEA

Pesticide Environmental Accounting Tool

IPM

PEA

Pesticide Environmental Accounting Tool

= CONTRIBUTION OF NATURAL PREDATORS TO THE REDUCTION OF DIRECT AND INDIRECT COSTS OF PEAR PRODUCTION

11. Concluding remarks

(i) to quantify the link between the loss of species and the provisioning of ecosystem services (biological pest control)

(ii) to quantify the economic losses which can be attributed to a reduction of natural predators

(iii) To develop a methodological framework for the valuation of non-marketable species based on their ecological role within the ecosystem (ecosystem based approach for the valuation of biodiversity)

➡ Stress the importance of including the functional role of species when attempting to value nonmarketable species

➡ stress the need for the integration of full ecological and economic models in policy making

Thank you!

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