

# HARMVECT - a simulation-based tool for pathway risk maps of invasive arthropods in Belgium

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**ILVO**

Instituut voor Landbouw-  
en Visserijonderzoek

# FPS HarmVect project

## Objective:

- Map international trade routes and animal and plant traffic to Belgium as to identify pathways by which exotic detrimental insects can be introduced to Belgium.
- Determine the risks of introducing harmful insects to Belgium via the international entry ports (airport, seaport, etc.) and in function of the trade routes and commodities.

## Approach:

- Develop a tool simulating the introduction of an arthropod into Belgium via all its potential introduction pathways
  - > calculate risk indices and generate pathway risk maps.
- Guide the user in identifying all potential pathways related to the arrival of the assessed arthropod; further subdivide these pathways into the smallest possible individual pathway-segments
  - > specify which detailed data has to be gathered and fed into the tool.
- “Propagule pressure” is used as parameter to quantify the risk.

# FPS HarmVect project

The tool is written in the open source R programming language and run in the Rstudio application Shiny, the latter is used to build a user-friendly interface.

No rocket-science simulations, but a simple, user-friendly tool collecting all necessary information and combining all successive introduction stages.

The tool has been developed using 10 model invasive organisms, plant threatening arthropods:

- *Tuta absoluta*
- *Drosophila suzukii*
- *Thrips palmi*
- *Bemisia tabaci*
- *Bactrocera invadens*

human and animal threatening arthropods :

- *Aedes albopictus*
- *Culicoides imicola*
- *Anopheles gambiae*
- *Rhipicephalus (Boophilus) microplus*
- *Dermacentor reticulatus*

# HarmVect - General

The screenshot displays the HarmVect web application interface. At the top, there is a navigation bar with tabs for Files, Plots, Packages, Help, and Viewer. Below this, the main header reads "HARMVECT". On the left side, a vertical sidebar contains a list of menu items: General (highlighted in blue), Countries of origin, Matrix, Traits of invasive arthropod, Import, Natural spread, Create and edit files, Compute propagule pressure, Point-of-entry, Risk Map, and Report. The main content area is titled "General" and contains the following information:

- Current basic directory:** C:/Users/nberkvens/Desktop/HarmVect\_shiny
- Name of sub-directory to save files:** A text input field containing "Tuta" and a "Set sub-directory" button.
- Actual working directory:** C:/Users/nberkvens/Desktop/HarmVect\_shiny/Tuta
- Invasive species:** A section with the following details:
  - Name invasive species:** A text input field containing "Tuta absoluta" and a "Set species name" button.
  - Species name:** Tuta absoluta

User submits general information used to automatically create, save and load tailored files throughout the tool

# HarmVect – Countries of origin

The screenshot shows the HarmVect web application interface. The top navigation bar includes 'Files', 'Plots', 'Packages', 'Help', and 'Viewer'. Below this is a toolbar with icons for home, back, and a red stop button. The main header is 'HARMVECT'. On the left is a sidebar with a 'General' section containing a blue button labeled 'Countries of origin', and other options like 'Matrix', 'Traits of invasive arthropod', 'Import', 'Natural spread', 'Create and edit files', 'Compute propagule pressure', 'Point-of-entry', 'Risk Map', and 'Report'. The main content area has tabs for 'Europe', 'America', 'Africa', 'Asia', and 'Oceania'. The 'America' tab is active, showing three columns: 'America 1', 'America 2', and 'America 3'. Each column lists countries with checkboxes. A 'CLEAR ALL' button is at the bottom of the list.

America 1	America 2	America 3
<input type="checkbox"/> Antigua and Barbuda	<input type="checkbox"/> Cuba	<input type="checkbox"/> Nicaragua
<input checked="" type="checkbox"/> Argentina	<input type="checkbox"/> Dominica	<input checked="" type="checkbox"/> Panama
<input type="checkbox"/> Aruba	<input type="checkbox"/> Dominican Republic	<input checked="" type="checkbox"/> Paraguay
<input type="checkbox"/> Bahamas	<input checked="" type="checkbox"/> Ecuador	<input checked="" type="checkbox"/> Peru
<input type="checkbox"/> Barbados	<input type="checkbox"/> El Salvador	<input type="checkbox"/> Saint Kitts and Nevis
<input type="checkbox"/> Belize	<input type="checkbox"/> Grenada	<input type="checkbox"/> Saint Lucia
<input checked="" type="checkbox"/> Bolivia	<input type="checkbox"/> Guatemala	<input type="checkbox"/> Saint Vincent and the Grenadines
<input checked="" type="checkbox"/> Brazil	<input type="checkbox"/> Guyana	<input type="checkbox"/> Suriname
<input type="checkbox"/> Canada	<input type="checkbox"/> Haiti	<input type="checkbox"/> Trinidad and Tobago
<input checked="" type="checkbox"/> Chile	<input type="checkbox"/> Honduras	<input type="checkbox"/> United States
<input checked="" type="checkbox"/> Colombia	<input type="checkbox"/> Jamaica	<input checked="" type="checkbox"/> Uruguay
<input checked="" type="checkbox"/> Costa Rica	<input type="checkbox"/> Mexico	<input checked="" type="checkbox"/> Venezuela

CLEAR ALL

User describes the current geographical distribution of the arthropod  
-> EPPO, CABI invasive compendium, ...

# HarmVect - Matrix

The screenshot shows the main interface of the HarmVect Matrix application. At the top is a menu bar with 'Files', 'Plots', 'Packages', 'Help', and 'Viewer'. Below the menu bar is a toolbar with icons for file operations. The main area is titled 'HARMVECT' and features a sidebar on the left with navigation links: 'General', 'Countries of origin', 'Matrix' (highlighted in blue), 'Traits of invasive arthropod', 'Import', 'Natural spread', 'Create and edit files', and 'Compute propagule pressure'. The main content area has tabs for 'Animal', 'Flowers', 'Vegetables' (selected), 'Fruits', 'Grains', and 'Plants'. Below these tabs are three columns: 'Vegetable 1', 'Vegetable 2', and 'Vegetable 3'. Each column contains a list of vegetables with checkboxes. In the 'Vegetable 2' column, 'Eggplants', 'Potatoes (ware)', and 'Tomatoes' are checked. The 'Vegetable 1' column has 'Beans' checked. The 'Vegetable 3' column has 'Peppers' and 'Potatoes (ware)' checked.

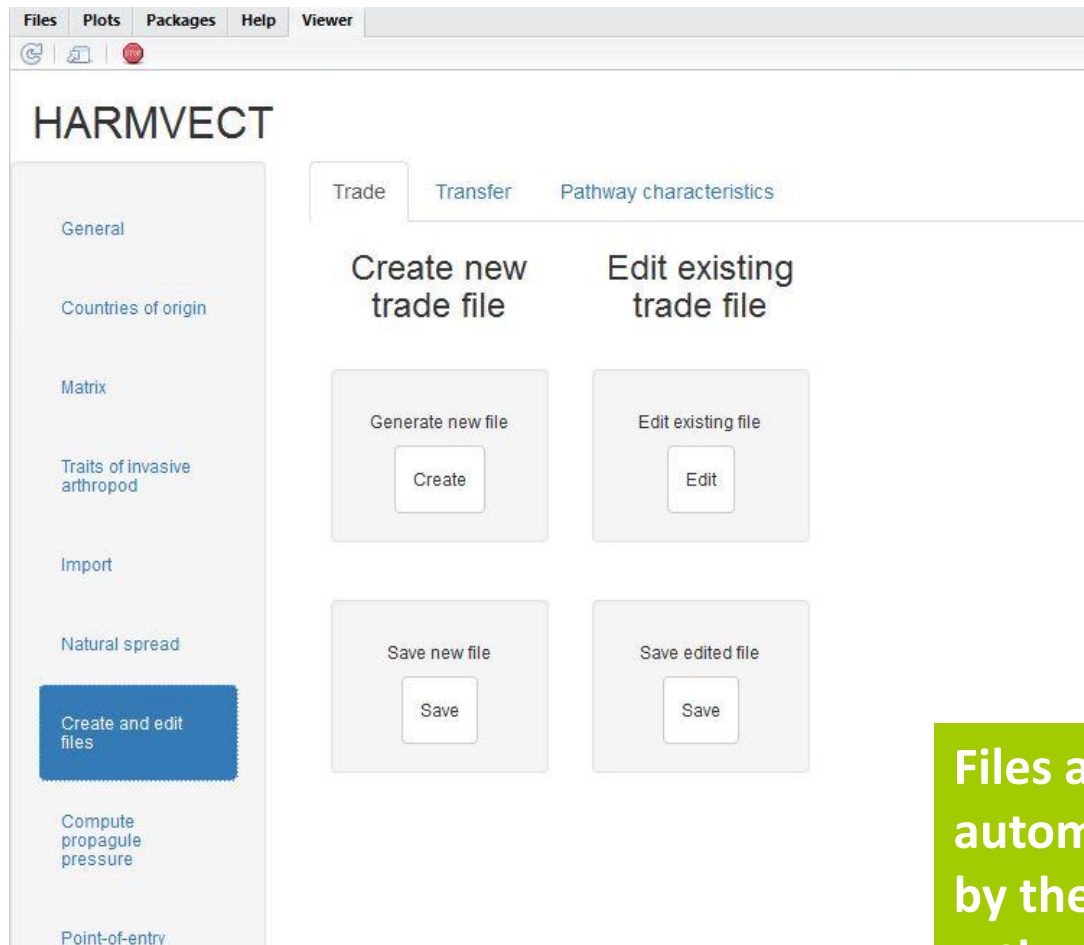
Vegetable 1	Vegetable 2	Vegetable 3
<input type="checkbox"/> Arrowroot	<input type="checkbox"/> Cucumbers	<input type="checkbox"/> Peas
<input type="checkbox"/> Artichokes	<input checked="" type="checkbox"/> Eggplants	<input checked="" type="checkbox"/> Peppers
<input type="checkbox"/> Asparagus	<input type="checkbox"/> Endive and other chicory	<input type="checkbox"/> Pickles
<input checked="" type="checkbox"/> Beans	<input type="checkbox"/> Fennel	<input type="checkbox"/> Potatoes (seed)
<input type="checkbox"/> Beetroot, salsify, radish and similar	<input type="checkbox"/> Garlic	<input checked="" type="checkbox"/> Potatoes (ware)
<input type="checkbox"/> Cabbage, white or red	<input type="checkbox"/> Horseradish	<input type="checkbox"/> Shallots
<input type="checkbox"/> Capers	<input type="checkbox"/> Jeruzalem artichoke and similar	<input type="checkbox"/> Spinach
<input type="checkbox"/> Capsicum spp (other)	<input type="checkbox"/> Kohlrabi, kale and similar	<input type="checkbox"/> Sprouts
<input type="checkbox"/> Carrots or turnips	<input type="checkbox"/> Leek	<input type="checkbox"/> Sweet potatoes
<input type="checkbox"/> Cauliflowers	<input type="checkbox"/> Leguminous vegetables (others)	<input type="checkbox"/> Sweetcorn
<input type="checkbox"/> Celeriac	<input type="checkbox"/> Letuce (Lactuca sativa)	<input type="checkbox"/> Taro
<input type="checkbox"/> Celery	<input type="checkbox"/> Letuce (other)	<input checked="" type="checkbox"/> Tomatoes
<input type="checkbox"/> Cep		<input type="checkbox"/> Truffles
<input type="checkbox"/> Chanterelles		<input type="checkbox"/> Yams
<input type="checkbox"/> Chard and cardoons		<input type="checkbox"/> Yautia
		<input type="checkbox"/> Other vegetables

User enlists the commodities the arthropod is associated with.  
List is based on Eurostat categories  
-> EPPO, CABI, ...

This screenshot shows a zoomed-in view of the 'Associated commodity' section of the HarmVect Matrix application. The sidebar on the left is identical to the previous screenshot, with 'Matrix' highlighted. The main content area has tabs for 'Animal', 'Flowers', 'Vegetables' (selected), and 'Fruits'. Below the tabs, there are five sections, each with a label and a text input field: 'Associated commodity 1' (containing 'Bamboo'), 'Associated commodity 2' (containing 'Enter commodity ...'), 'Associated commodity 3' (containing 'Enter commodity ...'), 'Associated commodity 4' (containing 'Enter commodity ...'), and 'Associated commodity 5' (containing 'Enter commodity ...').

New commodities can be added

# HarmVect – Create and edit



A first set of tailored files are created to acquire specific data related to:  
Trade – Transfer – Pathway characteristics

Files are automatically saved by the tool in the arthropod subfolder



# HarmVect – Create and edit

Data Editor

File Edit Help

	product	origin	infestRate	mean	air	sea	rail	road	ww
1	Beans	Albania	1e-12	0	0	0	0	1	0
2	Beans	Algeria	1e-12	0	0.5	0	0	0.5	0
3	Beans	Argentina	1e-12	0	1	0	0	0	0
4	Beans	Austria	1e-12	31	0	0	0	1	0
5	Beans	Bolivia	1e-12	0	1	0	0	0	0
6	Beans	Bosnia and Herzegovina	1e-12	0	0	0	0	1	0
7	Beans	Brazil	1e-12	0	1	0	0	0	0
8	Beans	Bulgaria	1e-12	1235	0	0	0	1	0
9	Beans	Chile	1e-12	0	1	0	0	0	0
10	Beans	Colombia	1e-12	0	1	0	0	0	0
11	Beans	Croatia	1e-12	0	0	0	0	1	0
12	Beans	Cyprus	1e-12	0	0	0.05	0	0.95	0
13	Beans	Ecuador	1e-12	0	1	0	0	0	0
14	Beans	Ethiopia	1e-12	210386	1	0	0	0	0
15	Beans	France	1e-12	29257570	0	0	0	1	0
16	Beans	Germany	1e-12	5088155	0	0	0	1	0

Transport data:  
Eurostat,  
TRACES (from  
2017)

Infestation rate is probably the most difficult  
parameter to gather information about  
-> EUROPHYT interception data, minor-major  
host data (EPPO, CABI)

Work directly in the file in  
the RStudio data editor or  
open the files in Excel

	product	air_mint	air_maxt	air_minrh	air_maxrh	air_light	sea_mint	sea_maxt	sea_minrh	sea_maxrh	sea_light	rail_mint	rail_maxt
1	Beans	2	6	75	95	0	2	6	75	95	0	2	6
2	Eggplants	8	12	75	95	0	8	12	75	95	0	8	12
3	Peppers	8	12	75	95	0	8	12	75	95	0	8	12
4	Potatoes (ware)	4.5	10	75	95	0	4.5	10	75	95	0	4.5	10
5	Tomatoes	16											
6	Gooseberries	0											
7	Melons	2											
8	Live plants for open ground	8											
9	Non-host cargo	0											

Pathway characteristics file:  
abiotic information concerning commodity transport



# HarmVect - Traits

Files Plots Packages Help Viewer

HARMVECT

General

Countries of origin

Matrix

Traits of invasive arthropod

Import

Natural spread

Create and edit files

Compute propagule pressure

Point-of-entry

Risk Map

Report

Invasive arthropod traits

-- Abiotic traits --

Temperature

Mortality thresholds

Rel humidity

Mortality thresholds

☐ Light effect

-- Biotic traits --

☐ Dormancy

☐ Cryptic behaviour

☐ Parthenogenesis

Reproductive rate

Dispersal capacity

Proportion females

Generation interval

Constant

Rico

Update traits from file

Save trait file

User describes “invasive” biological traits of the arthropod: EPPO, CABI, literature, ...

# HarmVect – Propagule pressure

Files Plots Packages Help Viewer

HARMVECT

General

Countries of origin

Matrix

Traits of invasive arthropod

Import

Natural spread

Create and edit files

Compute propagule pressure

Point-of-entry

Risk Map

Report

Compute propagule pressure

Compute

Trade						
Total	Air	Sea	Rail	Road	WW	Post
5066						
5074	2.625	2.295		5070		

Transfer						
Total	Air	Sea	Rail	Road	WW	Post
2.849						
2.855	1.299		0.0824	1.474		

Total Propagule						
Total	Air	Sea	Rail	Road	WW	Post
5069						
5077	3.924	2.295	0.0824	5071		

The tool calculates the propagule pressure via the various trade and transfer pathways and per transport medium

Divided per product						
prod	air	sea	rail	road	ww	post
Beans	0.00	0.00	0.00	0.00	0.00	0.00
Eggplants	0.05	0.00	0.00	71.09	0.00	0.00
Peppers	0.00	0.00	0.00	0.00	0.00	0.00
Potatoes (ware)	0.00	0.00	0.00	0.00	0.00	0.00
Tomatoes	2.57	2.28	0.00	4168.38	0.00	0.00
Gooseberries	0.00	0.00	0.00	0.00	0.00	0.00
Melons	0.00	0.00	0.00	0.00	0.00	0.00
Live plants for open ground	0.00	0.00	0.00	829.90	0.00	0.00
Non-host cargo	0.00	0.01	0.00	0.17	0.00	0.00
Tourism	1.30	0.00	0.08	1.47	0.00	0.00
Commuting	0.00	0.00	0.00	0.00	0.00	0.00
Military	0.00	0.00	0.00	0.00	0.00	0.00

# HarmVect - Import

The screenshot displays the HarmVect web application interface. At the top, there is a navigation bar with tabs for 'Files', 'Plots', 'Packages', 'Help', and 'Viewer'. Below this, the main title 'HARMVECT' is visible. On the left side, there is a sidebar menu with options: 'General', 'Countries of origin', 'Matrix', 'Traits of invasive arthropod', 'Import' (highlighted in blue), 'Natural spread', 'Create and edit files', 'Compute propagule pressure', 'Point-of-entry', 'Risk Map', and 'Report'. The main content area is divided into three columns: 'POE' (Point of Entry), 'POA' (Point of Arrival), and 'PP' (Propagule Pressure). Each column contains six rows of input fields. The 'POE' column has text input fields for 'POE 1' through 'POE 6'. The 'POA' column has a dropdown menu for 'POA 1' (currently showing 'Merebeke') and text input fields for 'POA 5' and 'POA 6'. The 'PP' column has numeric input fields for 'PP1' through 'PP6'. A green callout box at the bottom right contains the text: 'User submits information concerning intentionally imported propagules of the arthropod e.g. for biological control, scientific research, ... -> NPPO'.

POE	POA	PP
POE 1 Brussel	POA 1 Merebeke	PP1 1000
POE 2	POA 2 Aalst	PP2 0
POE 3	POA 3 Aalter	PP3 0
POE 4	POA 4 Aarschot	PP4 0
POE 5	POA 5	PP5 0
POE 6	POA 6	PP6 0

User submits information concerning intentionally imported propagules of the arthropod e.g. for biological control, scientific research, ...  
-> NPPO

# HarmVect – Natural spread

Files Plots Packages Help Viewer

HARMVECT

General

Countries of origin

Matrix

Traits of invasive arthropod

Import

Natural spread

Longitude

Latitude

Propagule

Longitude 1: 2.35

Latitude 1: 48.85

Propagule 1: 10000

Longitude 2: 2.35

Latitude 2: 48.85

Propagule 2: 0

Longitude 3: 2.35

Latitude 3: 48.85

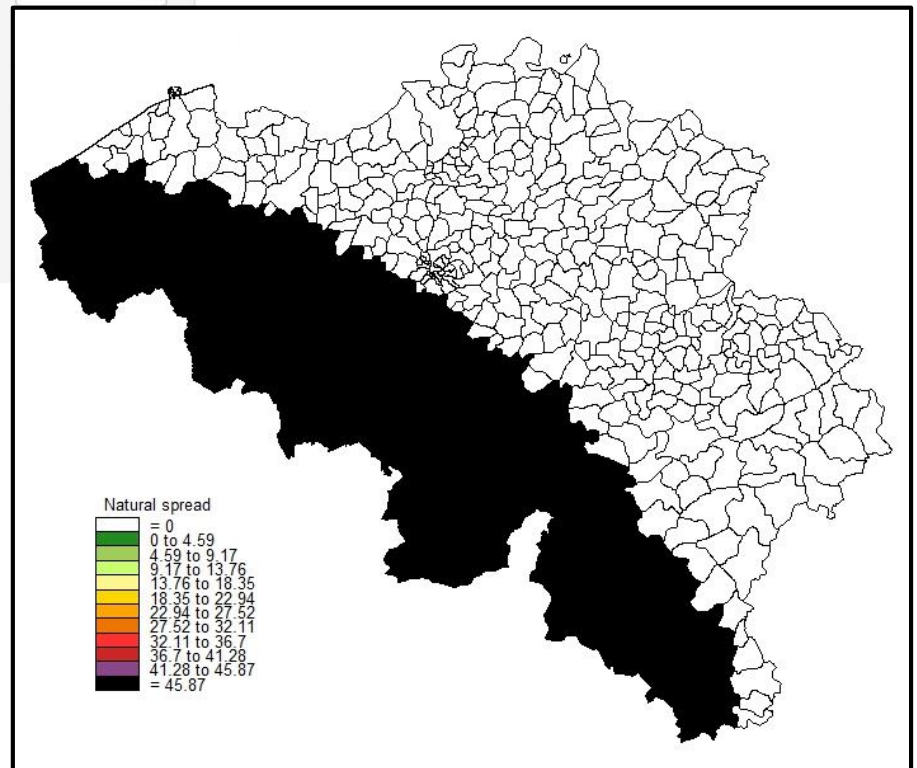
Longitude 4: 2.35

Latitude 4: 48.85

Longitude 5: 2.35

Latitude 5: 48.85

User describes “nearby” populations of the arthropod



# HarmVect – Pathway risk maps

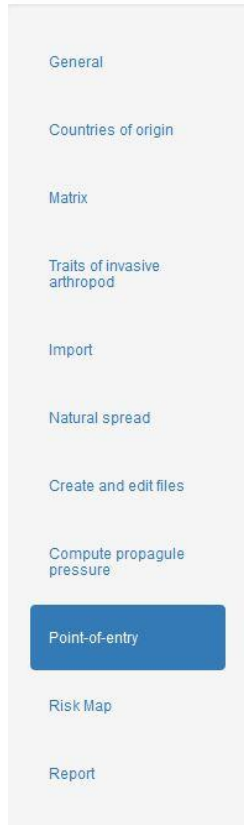
The tool generates 2 types of pathway risk maps:

- a) a Point-Of-Entry pathway risk map (POE); this map is based on entry at the national borders, thus generating concentrated hotspots as these points-of-entry are often international hubs absorbing intensive arrival of several pathways into the country;
- b) a Point-Of-Appearance pathway risk map (POA); this map is successive to the POE and visualizes the locations and level at which undetected propagules of the arthropod are exposed to the outside environment throughout Belgium.

# HarmVect - POE



## HARMVECT



Airport Harbour Rail Border Inland Harbours Post POE Map

Create new  
airport file

Edit existing  
airport file

Generate new file

Create

Edit existing file

Edit

Save new file

Save

Save edited file

Save

User creates tailored files describing distribution of the imported commodities via the different transport media

	Airport	Beans	Eggplants	Peppers	Potatoes...ware.	Tomatoes	Gooseberries	Melons	Live.plants.for.open.ground	Non.host.cargo
1	Antwerpen	0	0	0	0	0	0	0	0	0
2	Zaventem	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
3	Charleroi	0	0	0	0	0	0	0	0	0
4	Kortrijk	0	0	0	0	0	0	0	0	0
5	Grace-Hollogne	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
6	Oostende	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
7	Beauvechain	0	0	0	0	0	0	0	0	0
8	Bertrix	0	0	0	0	0	0	0	0	0
9	Steenokkerzeel	0	0	0	0	0	0	0	0	0
10	Chievres	0	0							
11	Florennes	0	0							
12	Tienen	0	0							
13	Peer	0	0							
14	Koksijde	0	0							
15	Hechtel-Eksel	0	0							
16	Wevelgem	0	0							
17	Saint-Hubert	0	0							
18	Knesselare	0	0							
19	Ravels	0	0							
20	Malle	0	0	0	0	0	0	0	0	0
21	Zutendaal	0	0	0	0	0	0	0	0	0

Airport file:  
distribution of each commodity per airport  
-> customs and NPPO (controllers)



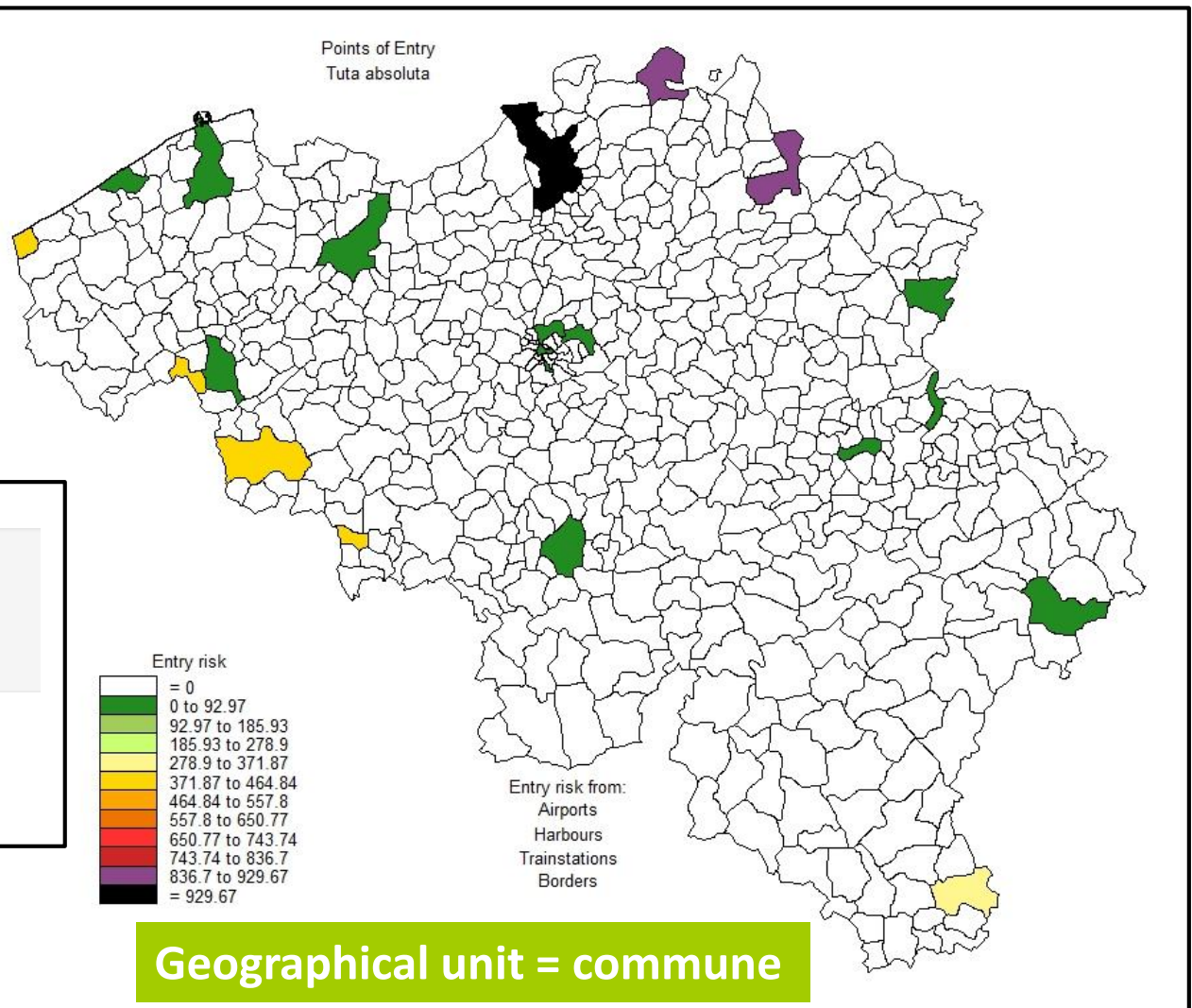
# HarmVect - POE

Risk = propagule pressure shown at points-of-entry

- ☒ Plot risk airports
- ☒ Plot risk harbours
- ☒ Plot risk railstations
- ☒ Plot risk border
- ☐ Plot risk inland harbours
- ☐ Plot risk mail
- ☐ Plot import risk

Create risk map at points-of-entry

The user can choose which risks to show





# HarmVect - POA

User creates tailored file describing the further scattering of the propagules throughout Belgium

Files
Plots
Packages
Help
Viewer

General
Countries of origin
Matrix
Traits of invasive arthropod
Import
Natural spread
Create and edit files
Compute propagule pressure
Point-of-entry
Risk Map
Report

Distribution file
Migration
POA Map
Host weighting file

Establishment maps
Risk Map

Choose Commune

Create new POA file

Generate new file

Create

Save new file

Save

Edit existing POA file

Edit existing file

Edit

Save edited file

Save

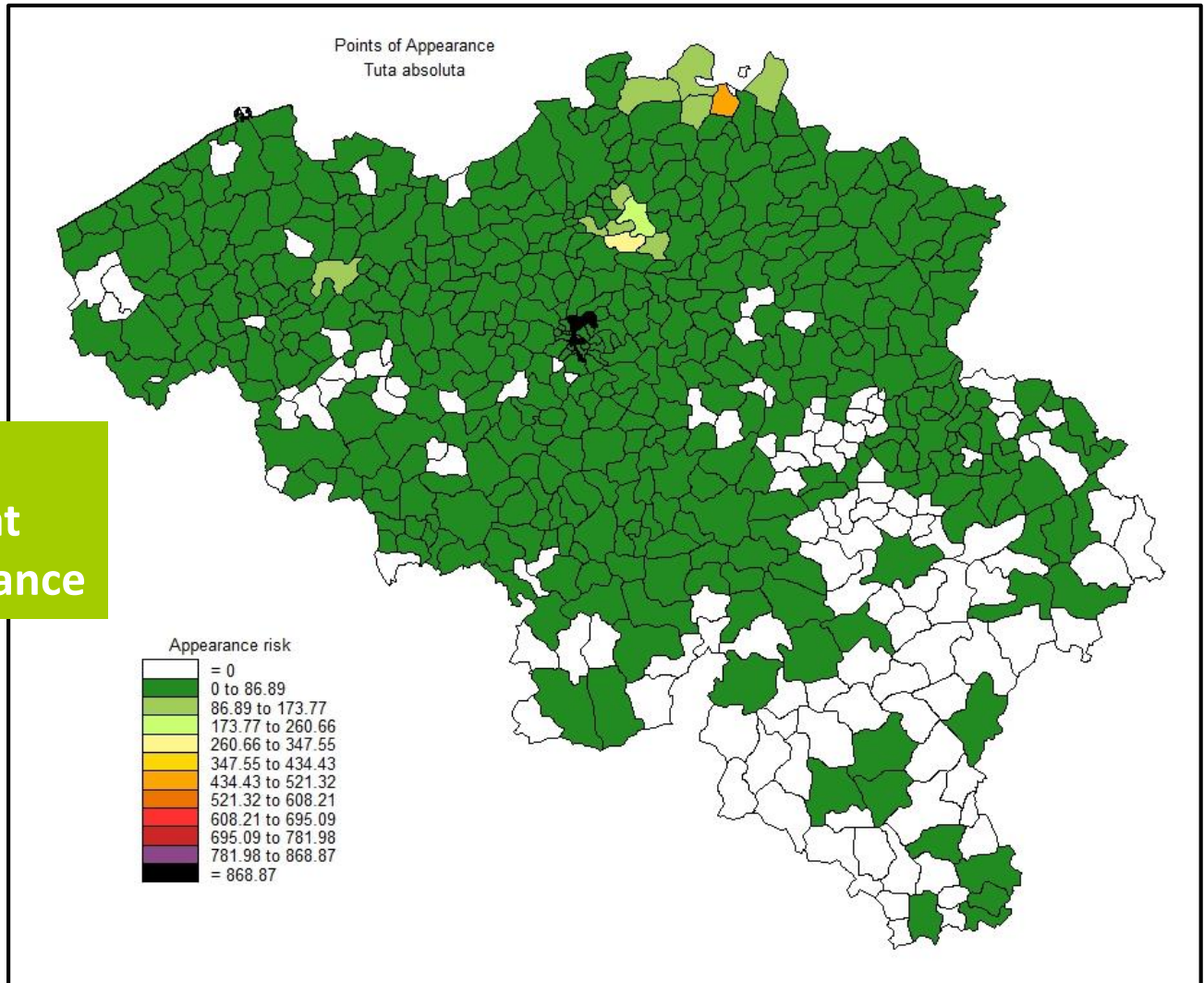
Data Editor
File Edit Help

	Distribute	Beans	Eggplants	Peppers	Potatoes..ware.	Tomatoes	Gooseberries
1	air	0.01	0.01	0.01	0.01	0.01	0.01
2	sea	0.01	0.01	0.01	0.01	0.01	0.01
3	rail	0.01	0.01	0.01	0.01	0.01	0.01
4	road	1e-12	1e-12	1e-12	1e-12	1e-12	1e-12
5	ww	0.01	0.01	0.01	0.01	0.01	0.01
6	post	0.01	0.01	0.01	0.01	0.01	0.01
7	pop	0.9	0.9	0.9	0.9	0.2	0.9
8	Deinze	0	0	0	0	0.02295082	0
9	Ardooie	0	0	0	0	0.01147541	0
10	Ingelmunster	0	0	0	0	0.01147541	0
11	Oudenburg	0	0	0	0	0.01147541	0
12	Ravels	0	0	0	0	0.02295082	0
13	Hoogstraten	0	0	0	0	0.03606557	0
14	Merkspas	0	0	0	0	0.1213115	0
15	Rijkevorsel	0	0	0	0	0.02295082	0
16	Brecht	0	0	0	0	0.01147541	0
17	Zedelgem	0	0	0	0	0.01147541	0
18	Wuustwezel	0	0	0	0	0.02295082	0
19	Beveren	0	0	0	0	0.01147541	0
20	Zwijndrecht	0	0	0	0	0.01147541	0
21	Kruikeke	0	0	0	0	0.01147541	0
22	Sint-Gillis-Waas	0	0	0	0	0.01147541	0
23	Rumst	0	0	0	0	0.02295082	0
24	Duffel	0	0	0	0	0.02295082	0
25	Sint-Katelijne-Waver	0	0	0	0	0.08196721	0
26	Lier	0	0	0	0	0.04918033	0
27	Putte	0	0	0	0	0.02295082	0
28	Boechout	0	0	0	0	0.03606557	0
29	Ranst	0	0	0	0	0.01147541	0
30	Brussel	0.1	0.1	0.1	0.1	0.2	0.1

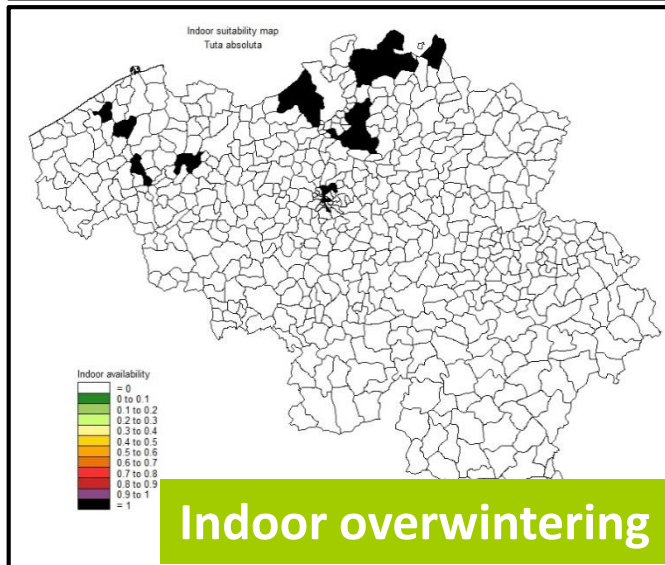
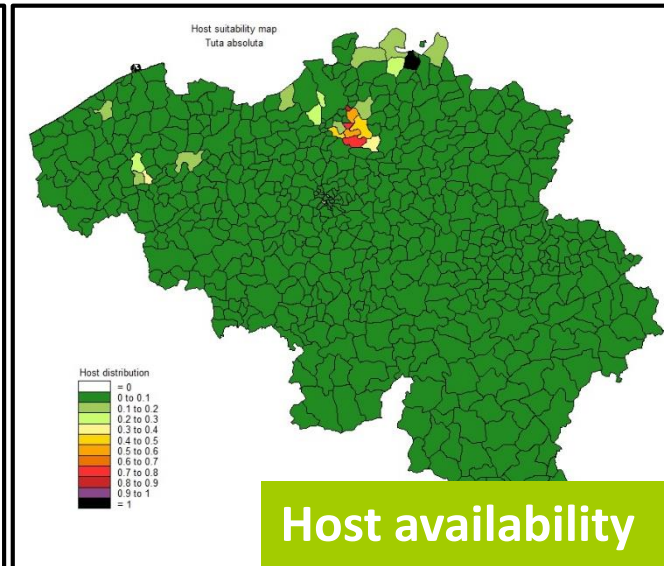
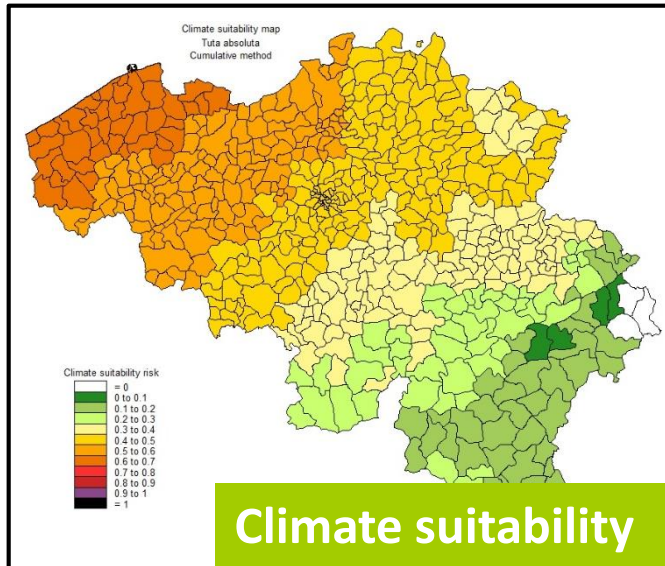
16

# HarmVect - POA

Risk = propagule  
pressure shown at  
points-of-appearance



# HarmVect – Combining maps



The user selects “weight” of each map in view of establishment capacity of the arthropod



# HarmVect – Risk map

Introduction (POA)

x

Host availability

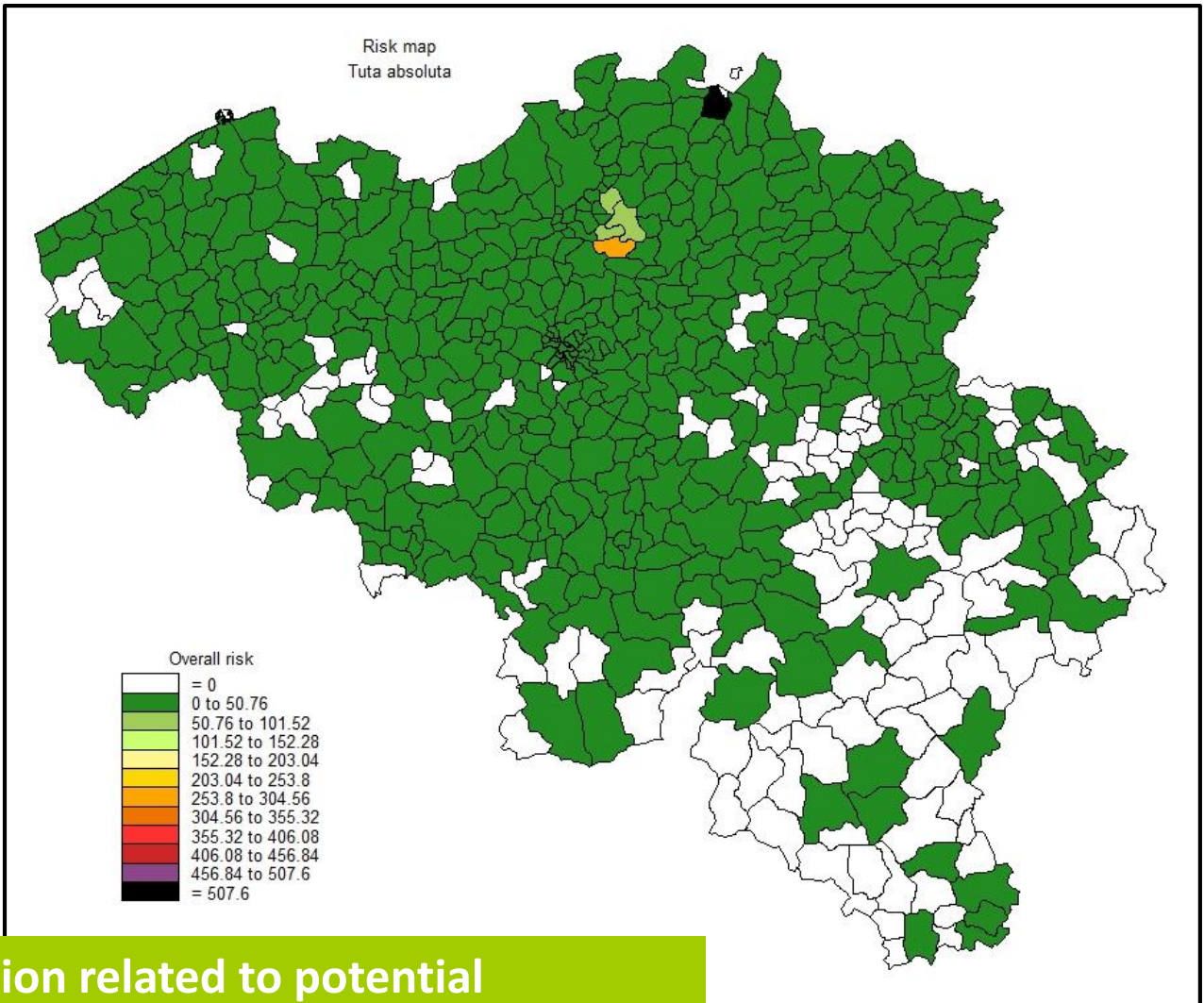
x

Climate suitability

x

Indoor

overwintering



Preliminary information related to potential establishment risk of the exotic arthropod in Belgium

# HarmVect - Report




Files

Plots

Packages

Help

Viewer



## HARMVECT

General

Countries of origin

Matrix

Traits of invasive arthropod

Import

Natural spread

Create and edit files

Compute propagule pressure

Point-of-entry

Risk Map

Report

Make sure genus map exists  
and genus\_poaMap.csv and genus\_poaMap.csv are up to date

☐ Overlay highways on POA map

Create report

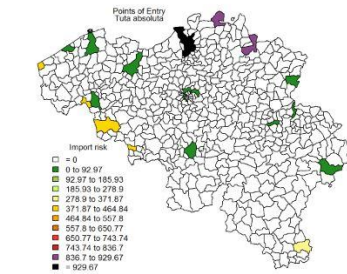
Import risk maps

14 november 2016

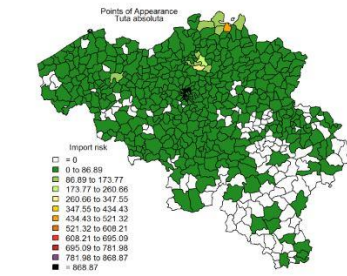
All warnings: package "raster" was built under R version 3.2.5

*Tuta absoluta*

Points-of-entry



Points-of-appearance



A .html report can automatically be compiled by the tool at the end of the analysis

Thank you for your  
attention

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and Fisheries Research  
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