The generation of wasted plastic pesticide containers in Greece and influencing parameters. A Life Cycle Assessment approach.

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Introduction (1/2)

- **Pesticides:** Control plant diseases and insects.
- **Pesticide containers:** Are mainly made out of HDPE
  - The amount of residual substances remaining in the container determine its classification as non-hazardous or hazardous waste in Europe.
- **Generation of WPPC:** In Greece it is estimated that 1000t/y of WPPC are generated. The majority of spent plastic pesticide containers in Greece ends up to the landfills.
- **Management of WPPC:** Triple rinsing-recycling-recovering.
- **Modeling attempts:** There seem to exist absolutely no modelling attempts to describe the quantities of wasted plastic pesticide containers as a function of various parameters

Introduction (2/2)

Figure 1. Uncontrolled disposal of WPPC

Goal of work

The **aims** of the study were:

(a) to **determine the weight of WPPC generated** in the study area per type of pesticide, type of crop and other factors,

(b) to **determine the parameters that significantly affect the generation** of WPPC after pesticide application,

(c) to **develop mathematical models** to describe the mass of WPPC as a function of selected significant parameters,

(d) to **validate the models** described in (c).

(e) to **determine the environmental aspects** of a less impactful management system of WPPC through life cycle assessment (LCA) methodology

Data collection (1/2)

- ✓ Data were obtained via questionnaires.
- ✓ The 106 farmers who participated in the survey lived in the Regional prefectures of Drama, Kavala, Kilkis, Imathia, Thessaloniki and Fthiotida.

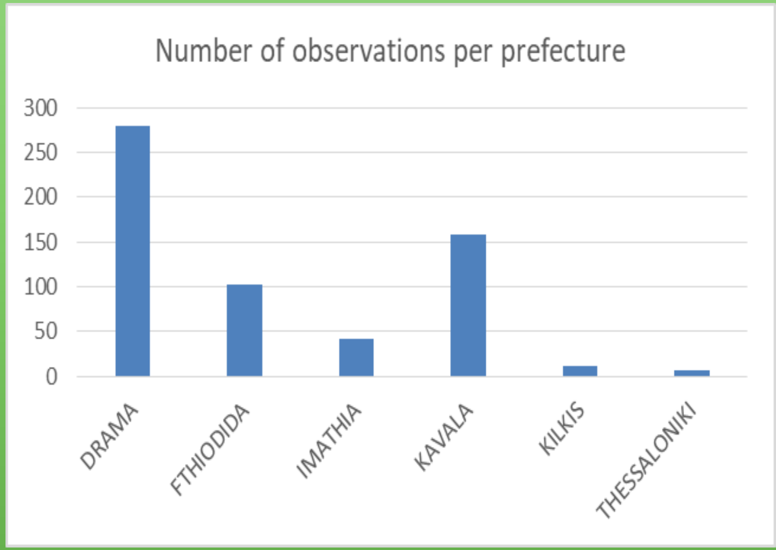

Figure 2. Number of observations per prefecture

Figure 3. Sampling points in Greece

- ✓ Random visits were realized to local coffee shops, agricultural shops and other places where farmers typically gather.

Data collection (2/2)

- ✓ We select 18 WPPC for the needs of LCA
- ✓ Half of the samples were triple rinsed with water
- ✓ Residual analysis was performed by Benakeio Phytopathological Institute
- ✓ Data were used through Life Cycle Assessment methodology

Survey development

- Each farmer filled up a questionnaire
- The parameters recorded were the volume of the container (L), the type of crop (annual, perennial), the type of irrigation (no irrigation, irrigated cultivation), the type of spraying (ground spraying, foliage spraying), the type of pesticide (insecticide, herbicide, fungicide, nematicide, acaricide), the application area of pesticide(m2) as well as others.
- Crop area is a rather obvious parameter that affects pesticide application amounts.
- The application on the soil of herbicides takes place prior to seeding which leads to higher demands compared to when the herbicide is applied on foliage.

Statistical analysis and regression equations

- The initial regression equation had the form:

$Y = a1 \bullet X1 + a2 \bullet X2 + \ldots + an \bullet Xn$ where:

Y: annual mass of empty pesticide containers in g (the dependent variable),

X_1 to Xn: the independent variables (predictors)

a_1 to an: the statistically significant coefficients.

- Minitab® v18 was used for the statistical analysis.

Model validation

- The following equation was used to calculate the validation error:

Y=(a-b)/b %

a=actual weight of WPPC(g),

b=predicted weight of WPPC (g)

Life cycle assessment (LCA) (1/3)

- Goal and scope definition
  - The functional unit of the study is 1 ton of generated WPPC.
  - The system boundary starts with the collection of WPPC and includes waste transport, waste treatment alternatives (recycling and incineration) and landfilling of waste.
  - Although, incineration is not currently applied as a technology for treatment of this kind of waste in Greece, it was included in our analysis as a potential alternative option

Life cycle assessment (LCA) (2/3)

Table 1. Alternative scenarios to manage WPPC that were evaluated under a life cycle assessment methodology

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Landfill	100%	50%	0%	50%	33.3%
Recycling	0%	0%	50%	50%	33.3%
Incineration	0%	50%	50%	0%	33.3%

Percentages are on a wet mass basis of the WPPC sent to each treatment technique

Life cycle assessment (LCA) (3/3)

- Life cycle inventory
  - Data for life cycle inventory was gathered from SimaPro PhD 8.2.3.0 database.
- Life cycle impact assessment
  - The assessment method chosen is the ReCiPe Midpoint (H) 1.12 version Europe Recipe H which refers to the normalization of Europe.
- Interpretation
  - In the current study, ReCiPe Midpoint (H) 1.12 version Europe Recipe H is used, but for sensitivity analysis, another method called EDIP 2003 version 1.05 is used.

Results (1/5)

- Linear empirical models were developed through regression.
- Four empirical models were developed which are included in Table 2 along with their validation errors.

Table 2. The four best reduced models calculated in the study

Model	Best reduced empirical model	R^2	Validation error
I (Insecticides, Herbicides, Fungicides, Nematicides, Acaricides, Growth regulators, Oils)	M = 13.8 (0.54) × AREA + 265 (94) × CROP + 811 (95) × IRRIG – 789 (103) × SPRAY	63.6%	-2.9%
II (Insecticides)	M = 6.7 (0.85) × AREA +294 (79) × CROP	33.8%	-39.6%
III (Herbicides)	M = 15.3 (0.76) × AREA +640 (253) × CROP + 827 (128) × IRRIG – 840 (156) × SPRAY	77.3%	-10.1%
IV (Fungicides)	M = 24.8 (2.6) × AREA	35.4%	-21.7%

Results (2/5)

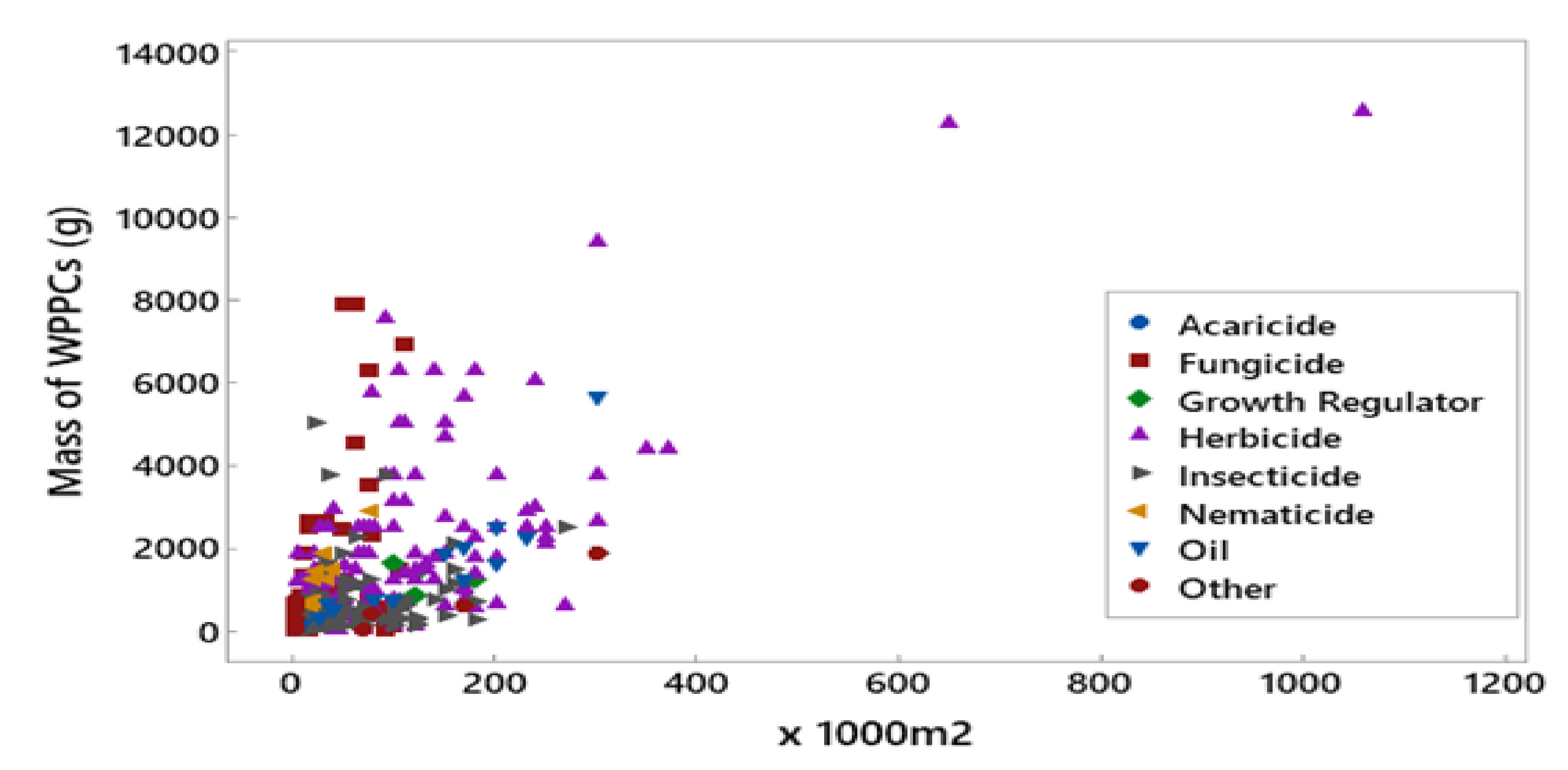

Figure 4. Scatter plot of WPPC generation rates vs area for the different types of pesticides

Results (3/5)

- The results of the LCA investigated for each impact category are as follows:
  - Climate change effect in scenario 2 is a result of the combustion of HDPE.
  - The best alternative against ozone depletion is scenario 2 which includes incineration.
- Normalization values indicated that terrestrial acidification, fresh water eutrophication, human toxicity, photochemical oxidation, particulate matter, fresh water ecotoxicity, marine ecotoxicity, natural land transformation and fossil depletion are the most significant impact categories for WPPC alternatives.

Results (4/5)

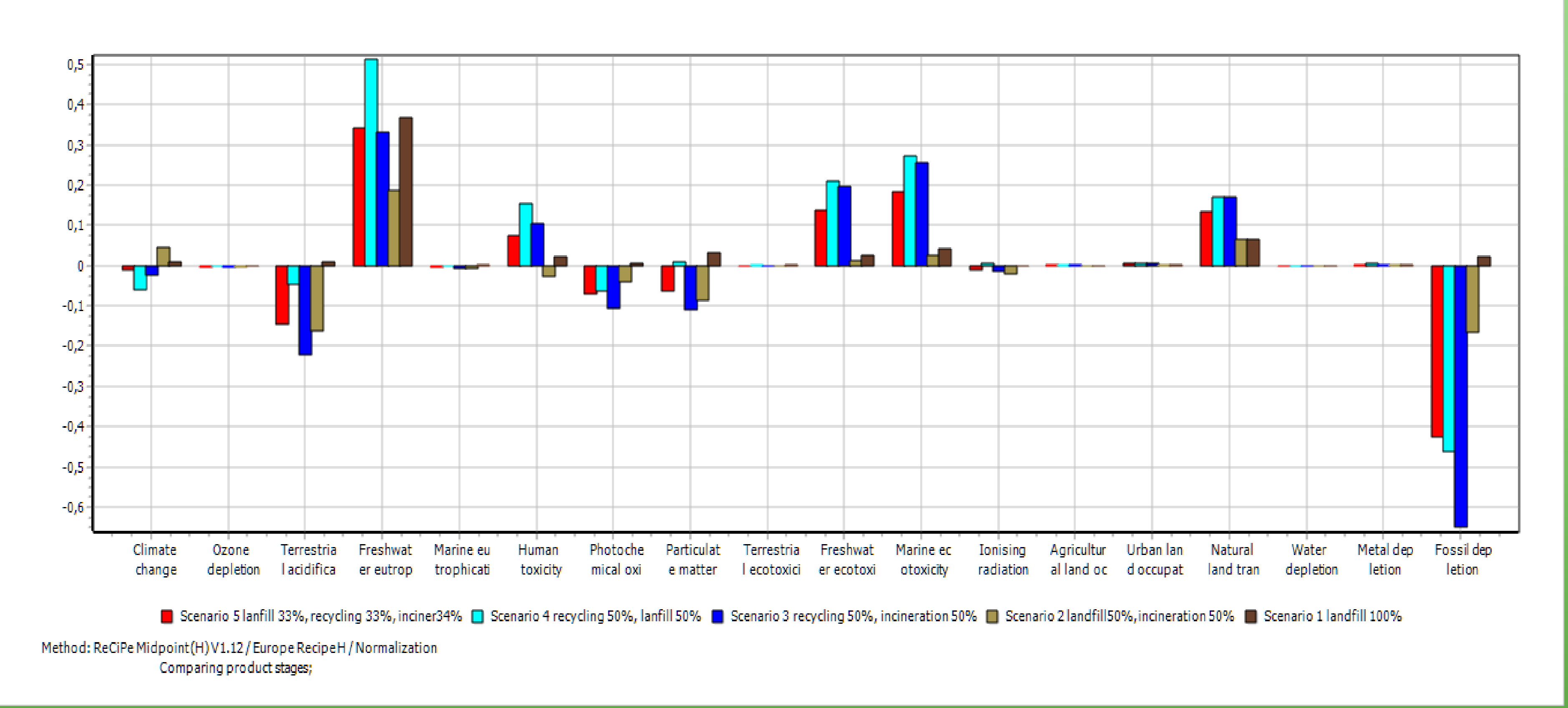

Figure 5. The results of the LCA normalization analysis

Results (5/5)

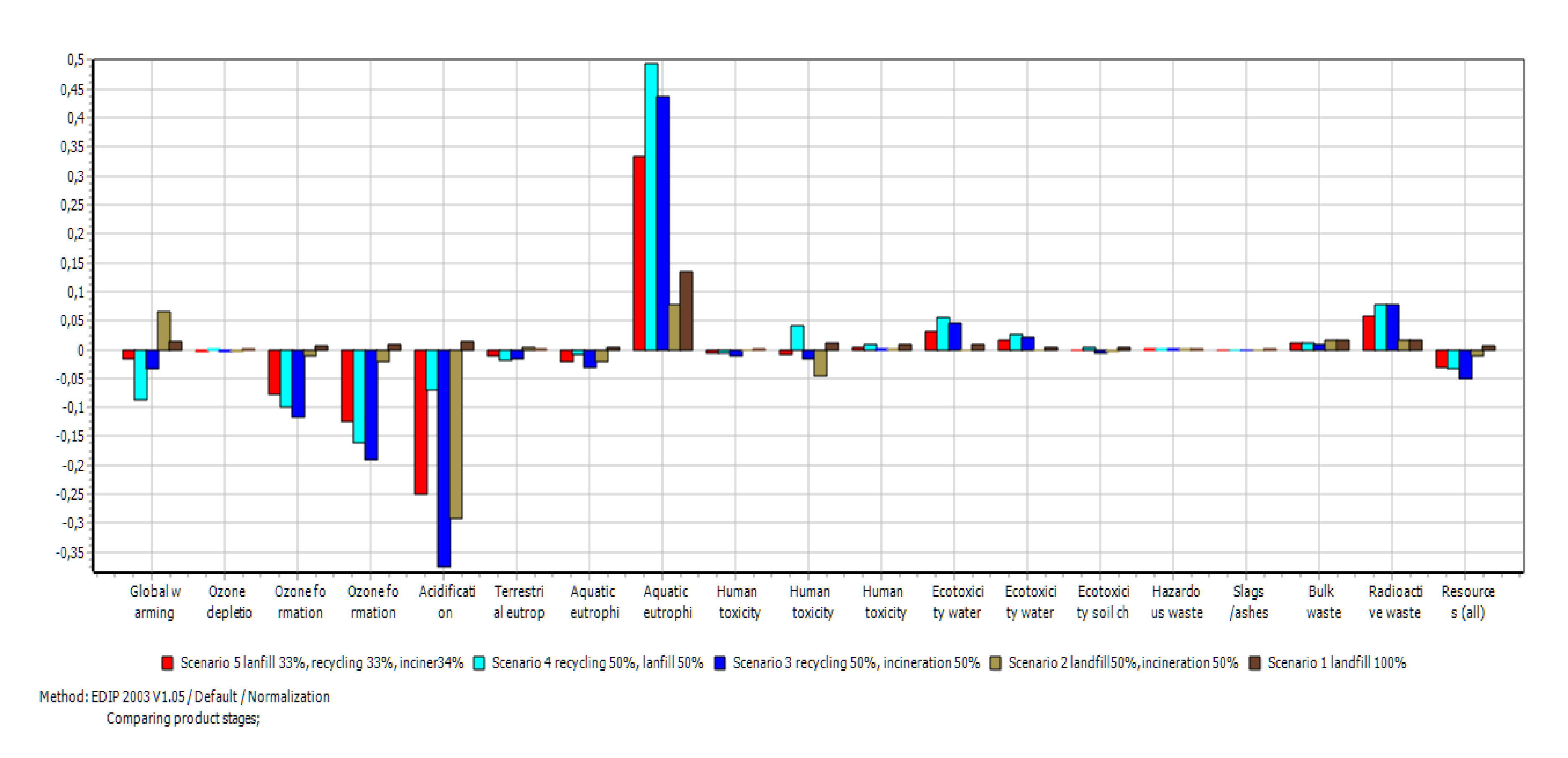

Figure 6 Sensitivity analysis with different impact assessment methods

Conclusions

- Crop area, the type of crop (annual-perennial, irrigated-dry) and the mode of application (on soil- on foliage) significantly affect the generation rates of WPPC.
- The generic model I and the herbicide model III are considered reliable to predict rates of the corresponding WPPC
- The most environmentally friendly WPPC management option is scenario 3, which includes recycling and incineration.
- Scenario 3 is the best option with higher environmental benefits but may not be economically sustainable owing to its high investment and operation costs.
- The present paper also pinpoints the need to establish a legal management framework for WPPC in Greece.

Thank you for your attention!