Ecotoxicity impact assessment as a tool to study impacts of hazardous substances – a case study for ecotoxicity impacts of pesticide usage in Finland

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LUONNONVARAKESKUS

Agenda

- Introduction (6)
- Aim (1)
- Material and methods (3)
- Results (3)
- Conclusions (2)
- Acknowledgements (1)

Introduction

Introduction:
Ecotoxicity impact assessment

- Chemicals are used in different steps of the product chain
  - e.g. plant protection products (=PPP) in the crop production in a field or industrial chemicals in the production of food packing materials
- Ecotoxic impacts of hazardous substances can be measured with the ecotoxicity impact assessment in LCA (=Life Cycle Assessment, ISO 14040:2006) per functional unit of the final product ≈ ecotoxicity footprint

➢ Impacts of different chemicals can be compared
  - e.g. active ingredients of PPPs
- Models for calculations
  - e.g. UsetoxTM

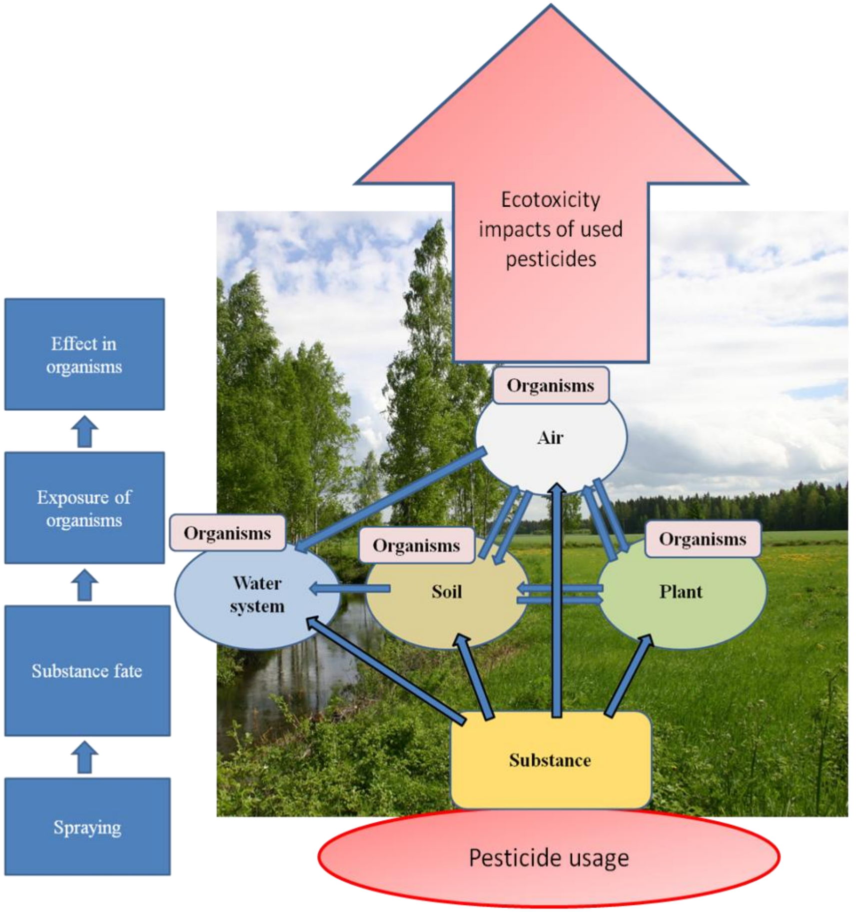


Figure. The potential ecotoxic impacts of pesticide emissions can be evaluated in LCA by modelling the environmental fate of active ingredient in air, water and soil and their exposure and effects on organisms.

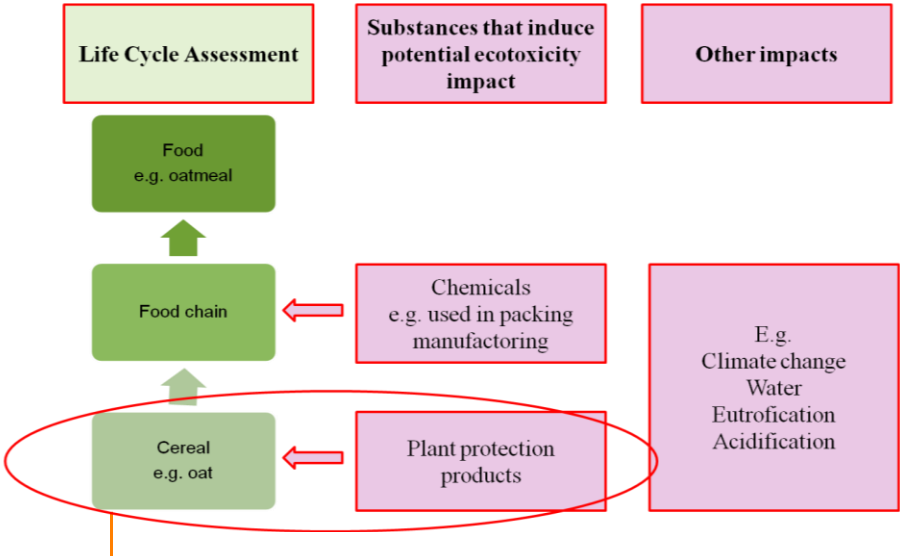
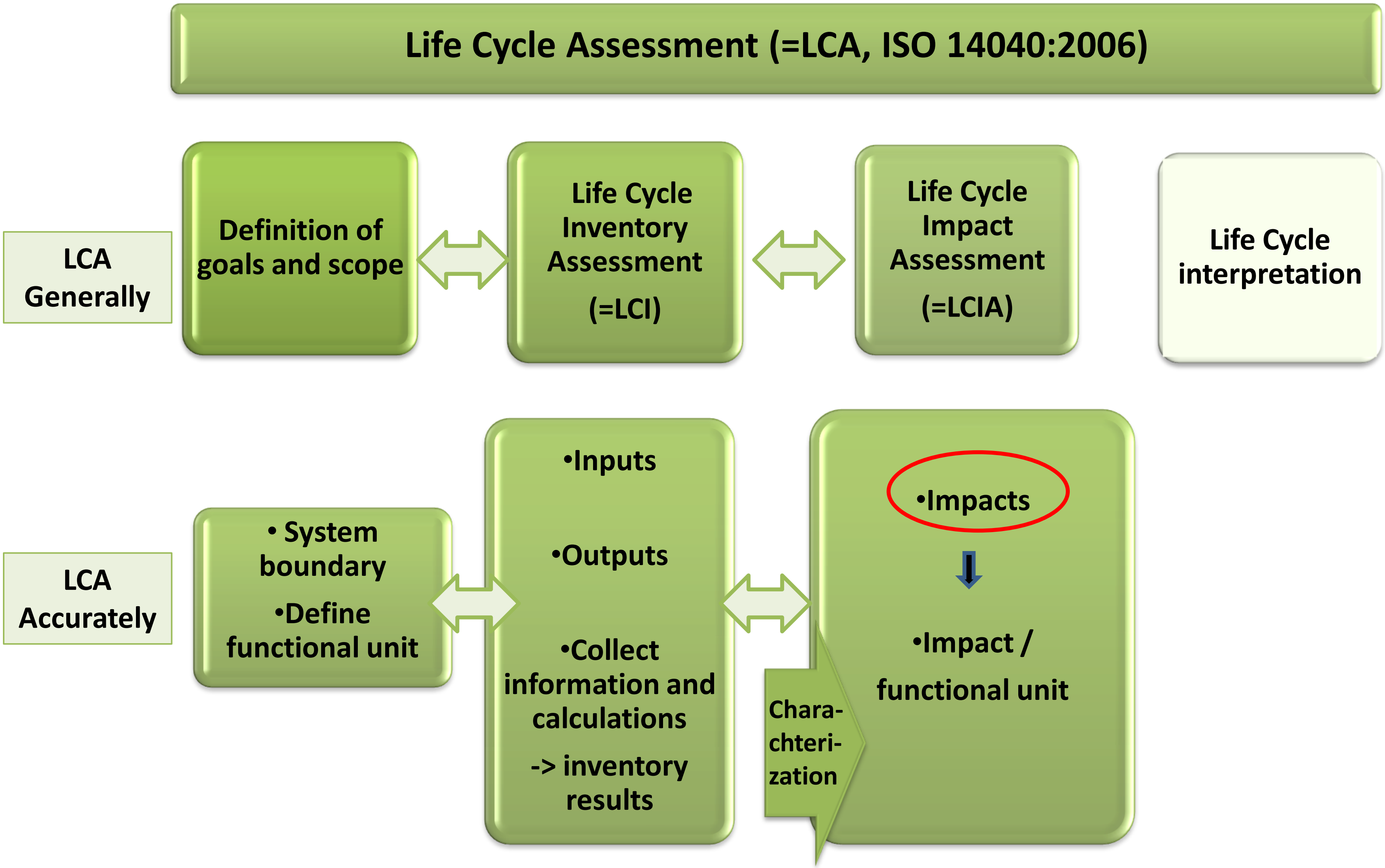


Figure. Forming of potential ecotoxicity in LCA. Circle illustrates the substance of our study.


Life Cycle Assessment (=LCA, ISO 14040:2006)
LCA Generally
Definition of goals and scope
Life Cycle Inventory Assessment (=LCI)
Life Cycle Impact Assessment (=LCIA)
Life Cycle interpretation
LCA Accurately
• System boundary
•Define functional unit
•Inputs
•Outputs
•Collect information and calculations
-> inventory results
Chara-chteri-zation
•Impacts
•Impact / functional unit

Introduction: Finland

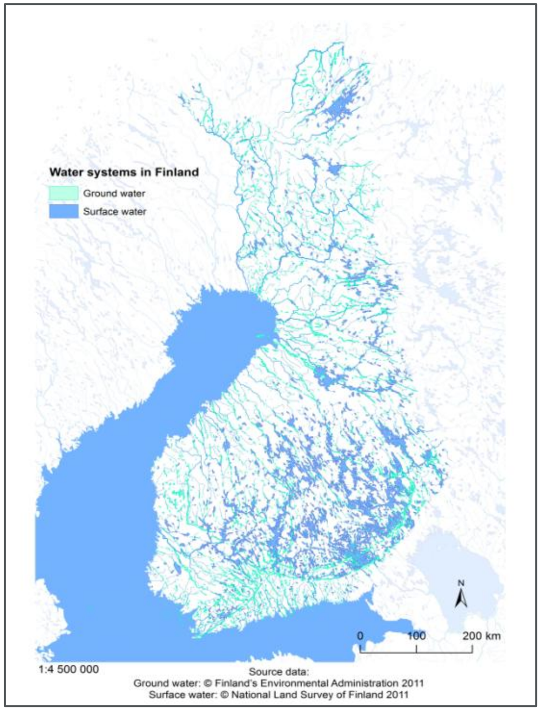


Figure. The land of the thousand lakes. Surface and ground water systems in Finland. (Map made by Eeva Lehtonen, MTT)

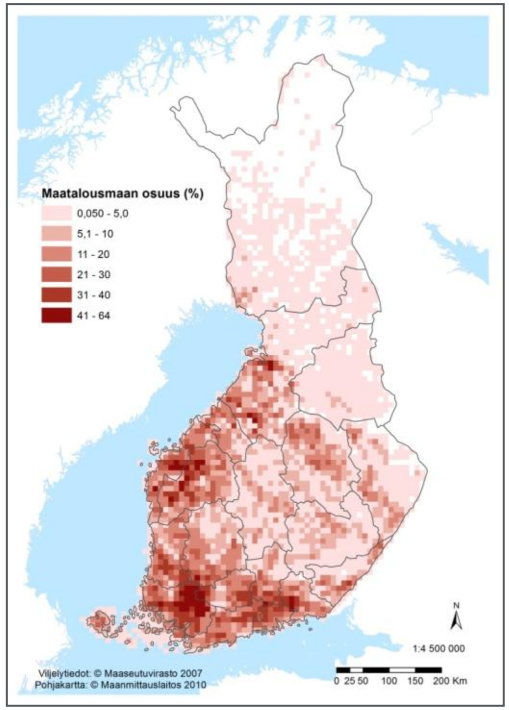


Figure. Agricultural land in Finland. (Map made by Eeva Lehtonen, MTT.)

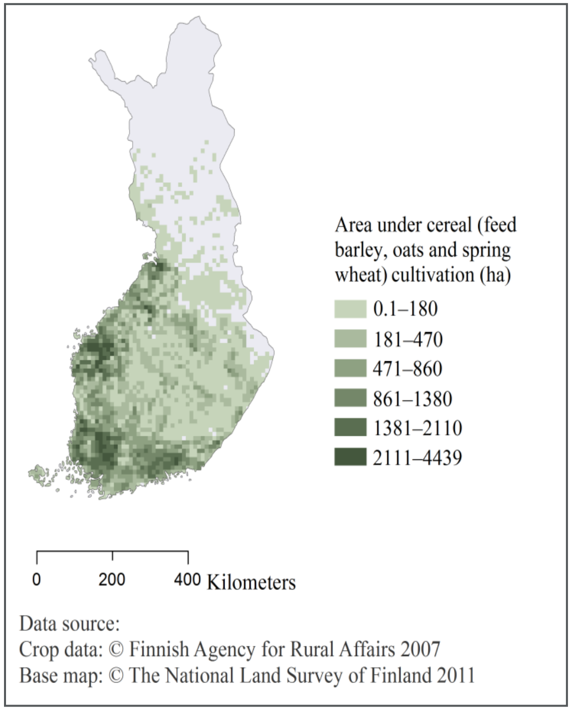


Figure. Feed barley, spring wheat and oats cover about 50 % of the total cultivated crop area in Finland. (Map made by Riikka Nousiainen, MTT.)

Year 2012	Area (ha)	From the total area of Finland (%)
Finland	39 090 300	100
Total land	30 389 300	77.8
Forests	23 000 000	59
Total arable and horticultural land	2 300 000	5.9
Plant cultivation	1 282 818	3.3
Organic cultivation	205 000	0.5
Fresh water	3 453 900	9
Sea water	5 247 100	13.4

Introduction:
Pesticide sales in Finland

- Finnish Safety and Chemicals Agency (TUKES)
  - does risk assessment, approves pesticides and sets risk mitigation methods
  - collects the sales data in Finland.
- In 2011
  - Total sales of active ingredients 1707.5 tonnes
  - 354 plant protection products
  - 154 active ingredients

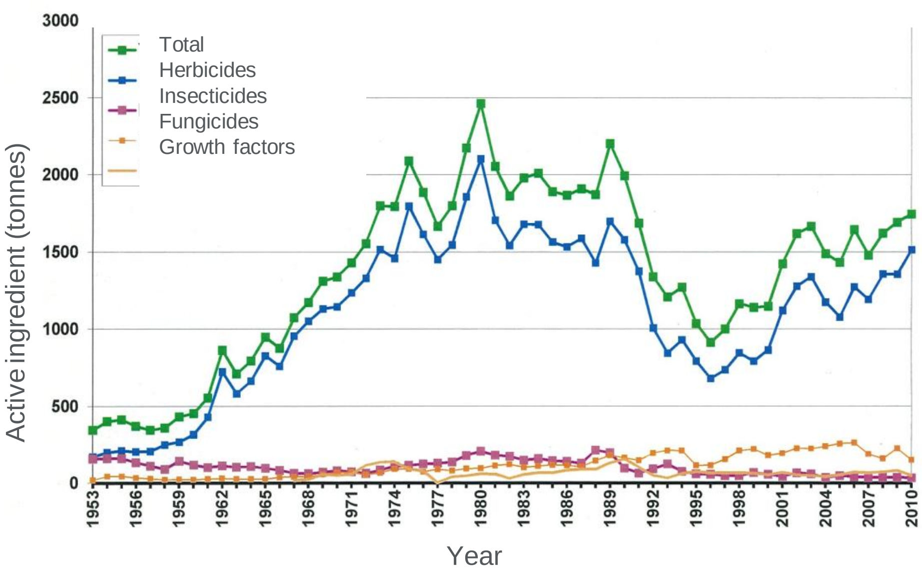


Figure. Pesticide sales in Finland over 1953-2010 (TUKES).

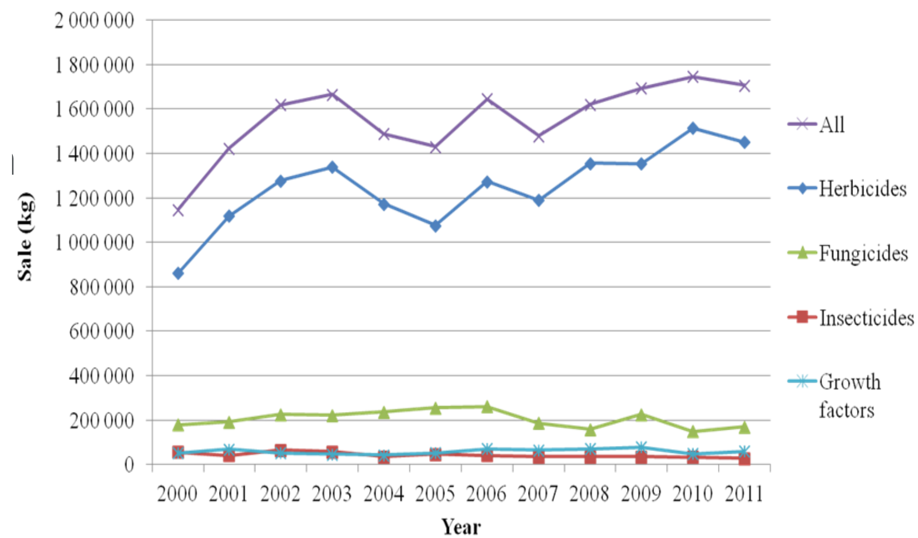


Figure. Sales data of agricultural plant protection products in Finland 2000-2011.

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Introduction:
Pesticide sales in EU

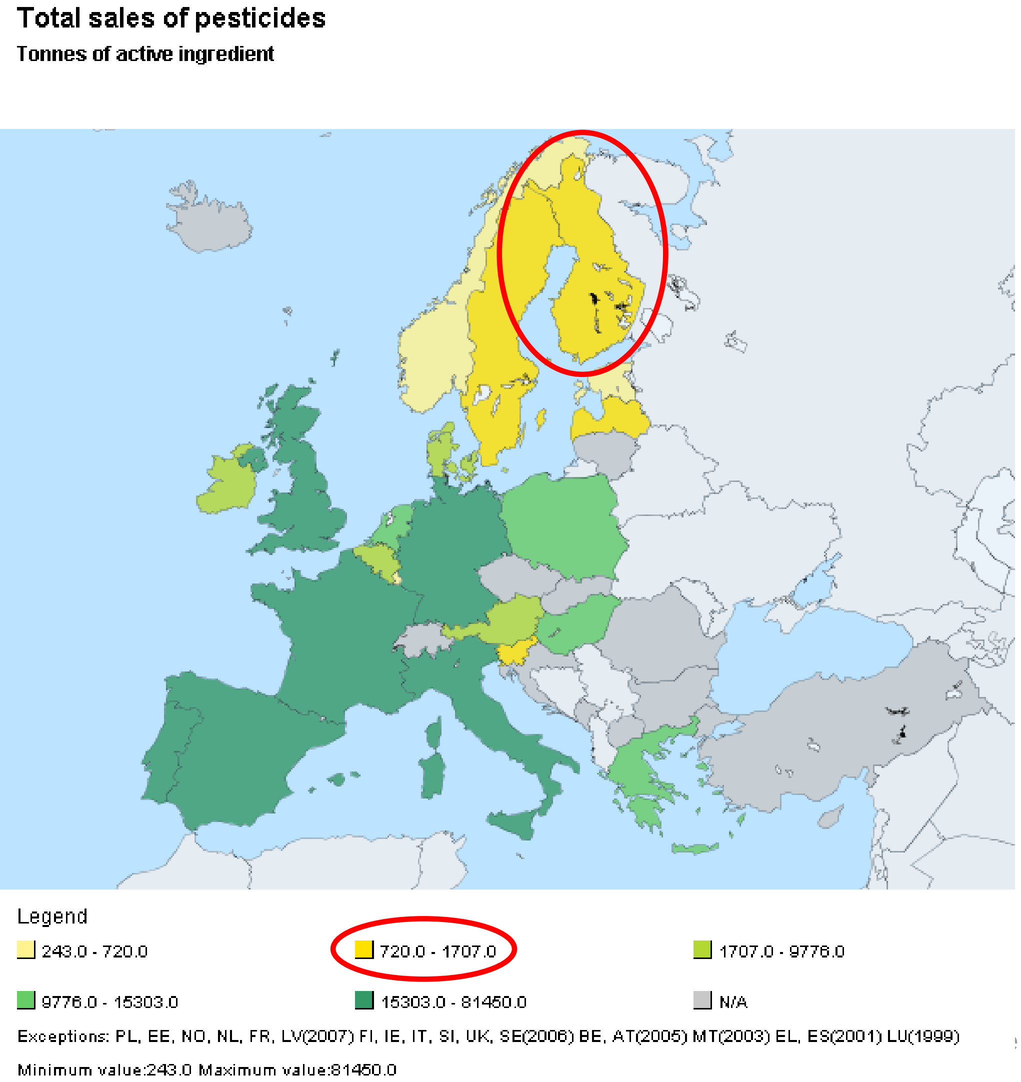

Figure. Total sales of pesticides in EU (Eurostat).

Introduction:
Pesticide usage in Finland

- To collect regularly the data of pesticide usage on target plants is rather new action in EU (1185/2009/EC).
- In Finland
  - Luke is collecting the usage data, was first time published in December 2014 covering a growth season 2013 http://www.maataloustilastot.fi/en/tilasto/4083
  - Before this a pilot data from a year 2007 Pesticide usage on cereals in Finland 2007

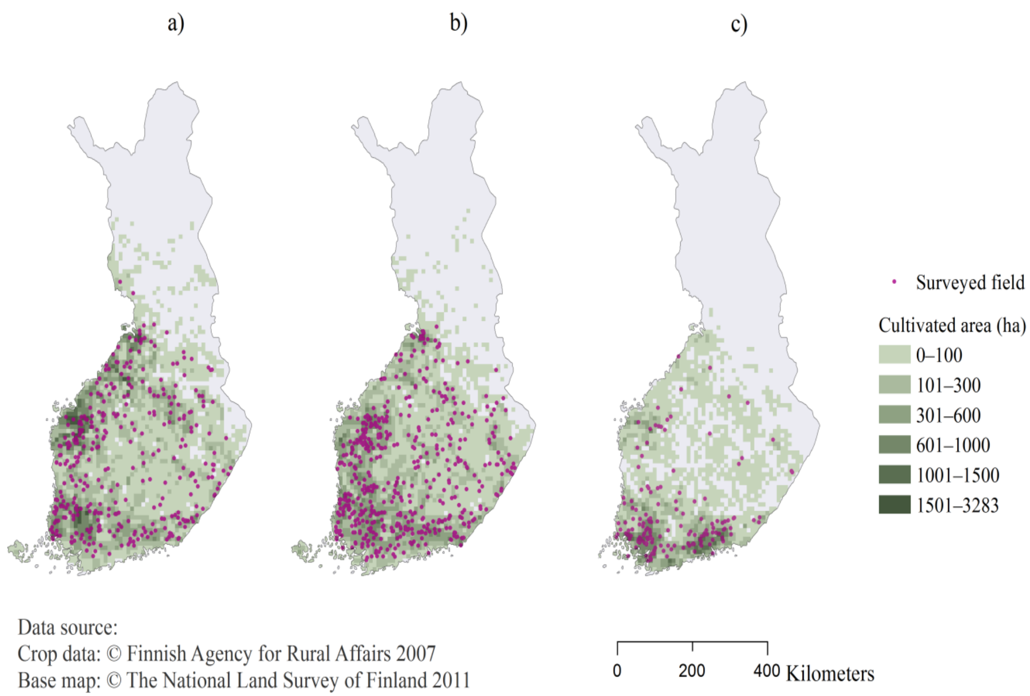

Figure. Pesticide usage of a case data in 2007 in Finland. Pesticide usage on cereal fields (purple dots) of a) feed barley (471 fields), b) oats (500 fields) and c) spring wheat (157 fields) (total 1,128 fields ha).

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Aim

Aim

- To quantify the ecotoxicological pressure of pesticides in Finland between 2000 and 2011, and to identify the main causes and substances causing the impact
  - ➢ Can help in developing policies and management practices to reduce the hazards from pesticide use
- Research questions:

1. How did the ecotoxic impact change over the period?
2. Which substance groups cause the most impacts?
3. Which were the most hazardous substances?

Materials and methods

Material and methods: Pesticide data

- Agricultural plant protection product (=PPP) sales data -> active ingredient kg/year
- Sales data from by Finnish Chemical Agency (Tukes)
- Over the years 2000-2011
- Included in total 176 active ingredients
- E.g. in 2011 herbicides were the most used ones from the total 1707.5 tons (0.7 kg/ha in the total agricultural land)

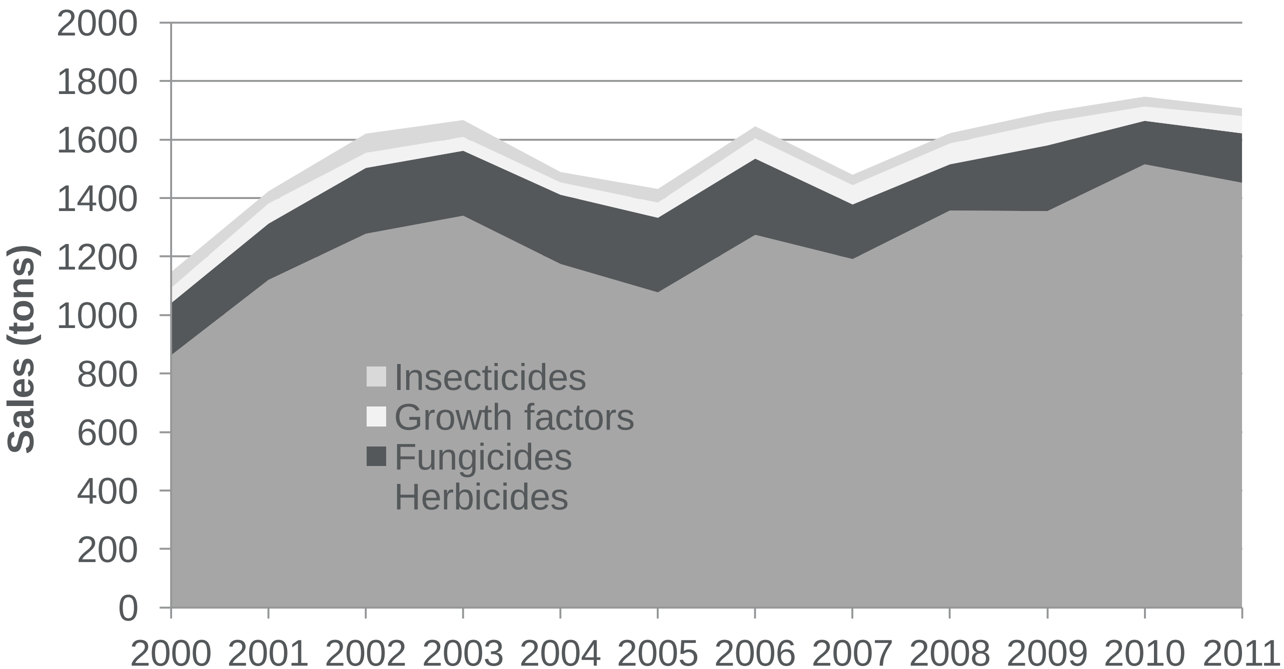

Figure. Pesticide sales (tons) for different substance groups in Finland over 2000-2011. Charts are presented in the order of decreasing sales: herbicides, fungicides, growth regulators and insecticides.

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Material and methods:
The model to calculate pesticide fate

- PestLCI 2.0 (Dijkman et al. 2012) was used to model emission fate assuming average Finnish field conditions.
  - For pesticides which were used in several variable months and growth stages, several emission factors were calculated and a weighted average was used to estimate overall emissions. In total, over 220 target applications were assessed.
  - Modelling was done for 75 active ingredients.

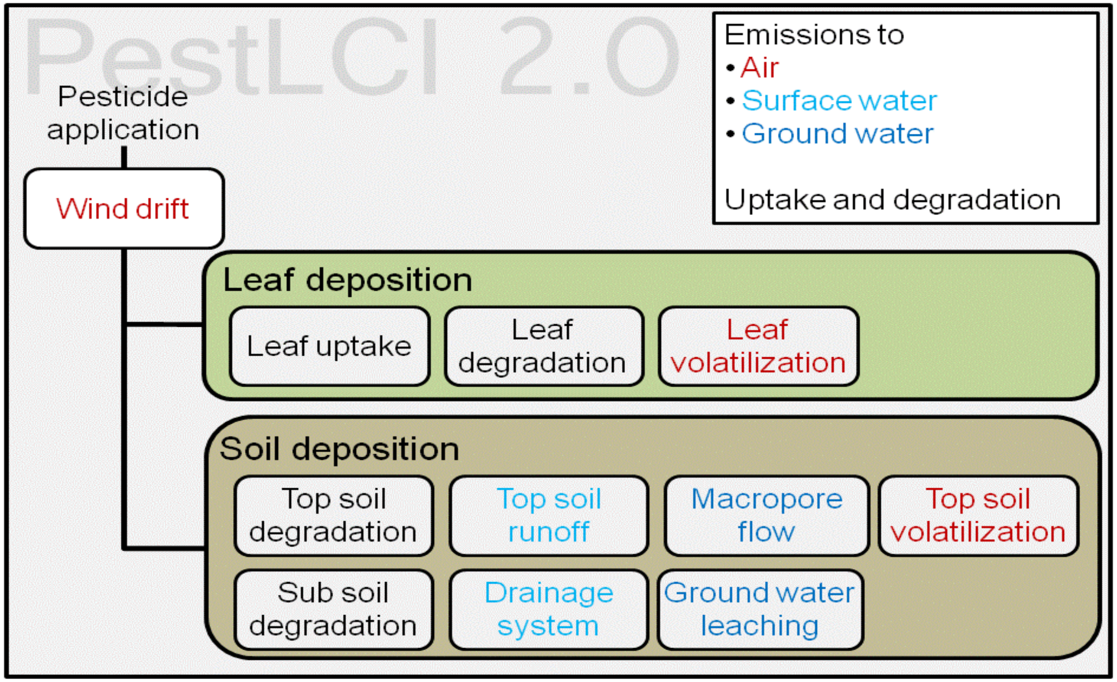

Figure. PestLCI 2.0

Material and methods:
The model to calculate potential ecotoxicity impacts

- SETAC consensus LCIA model USEtox™ (version 1.01) (Rosenbaum et al. 2008, Usetox™ 2013) were used to calculate characterization factors. The model was customized to fit Finnish regional environmental conditions by obtaining the relevant parameters from GIS.
  - Final result: a potential ecotoxic pressure (= impact score, CTU as an unit) describes the potentially affected fraction of species in the environment induced by the usage a PPP
  - Values were calculated for 63 active ingredients

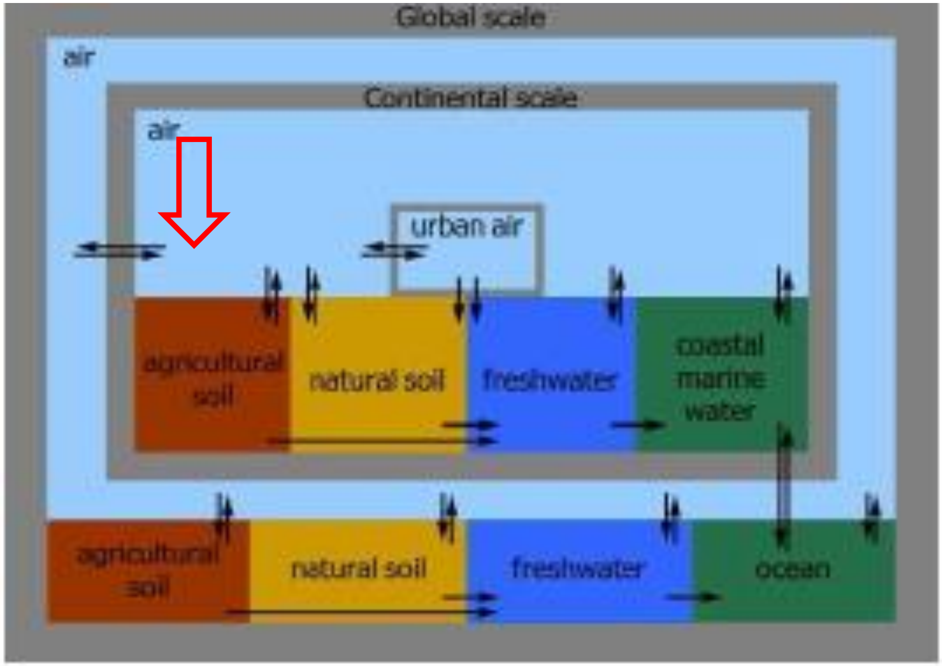

Figure. USEtox structure. USEtox is officially endorsed by the UNEP/SETAC Life Cycle Initiative, recommended in the ILCD Handbook for assessing toxicity in life cycle impact assessment (JRC-IES, 2011). It is also used by the US EPA for risk priorization (e.g. Mitchell et al. 2013) and is applied in more than 200 LCA and comparative risk assessment studies (USEtox™, 2013).

Results

Results:
The total ecotoxicity pressure

- Overall ecotoxic pressure decreased over the time scale mainly because decreased sale amount of the main hazardous substance fluazinam.
- Single very hazardous substances had a strong increasing effect on the total impact.
- There was no correlation between sales amount and ecotoxic pressure

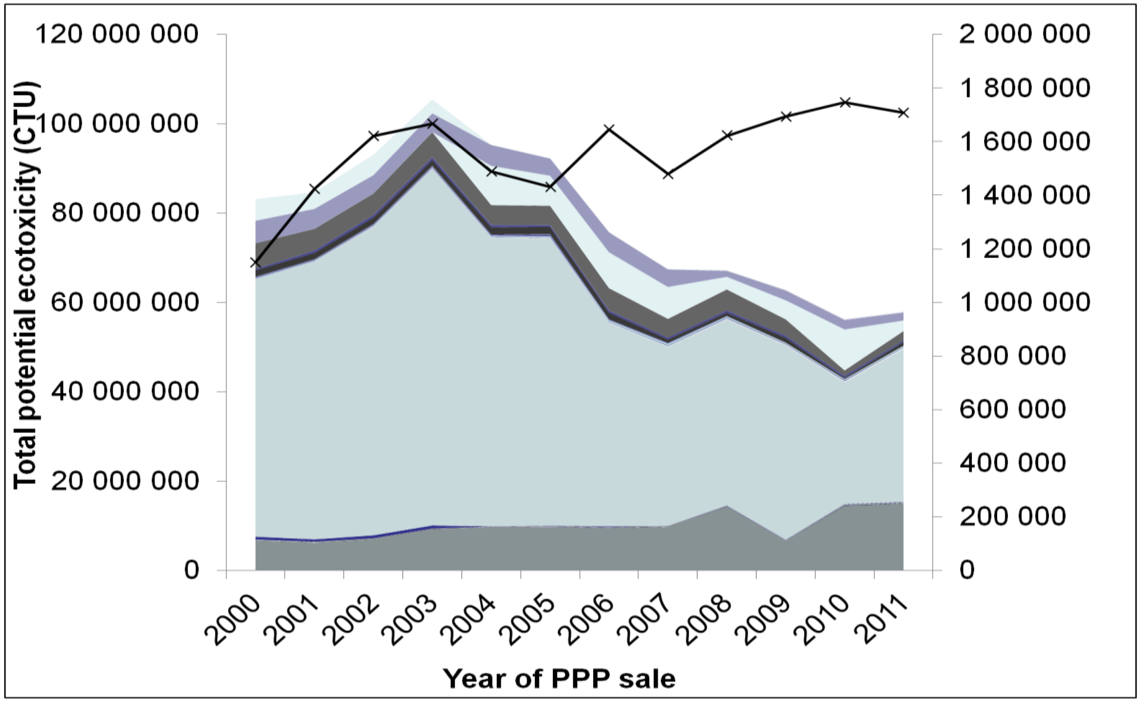

Figure. Potential ecotoxicity (in CTUs) for pesticides sold in Finland over 2000-2011. Line illustrates the total sales of pesticides (kg).

Results:
Ecotoxicity impacts by pesticide groups

- The main contributors to the total potential ecotoxic impact were fungicides.

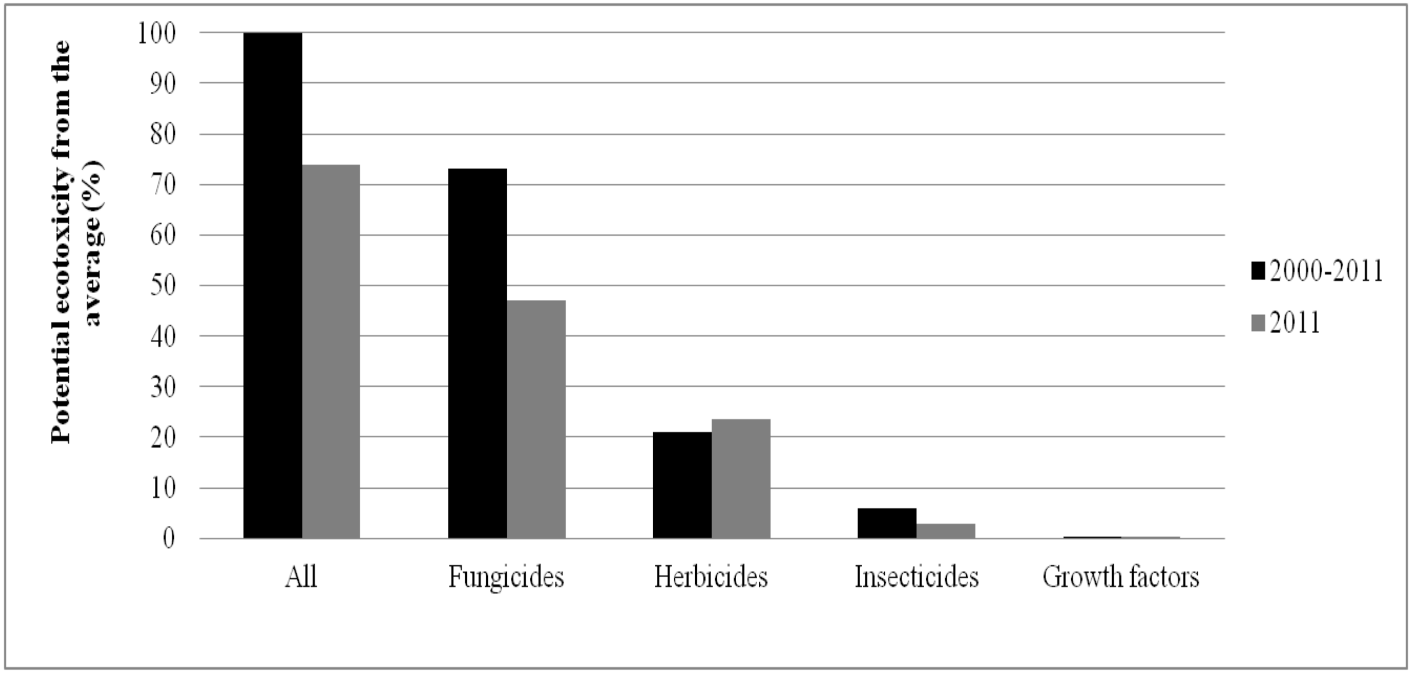

Figure. Pesticide substance groups in order to affect ecotoxicity pressure (in CTUs). Values are sum of average impacts per year of active ingredients in substance groups over 2000-2011 in Finland (%).

Results:
Ecotoxicity impacts by the most hazardous pesticides

- The most hazardous substances were fluazinam (used on potato), aclonifen (used mostly on peas, carrot and onion), methiocarb (strawberries), pendimethalin (carrot, onion), and prochloraz (cereals, oil seeds).

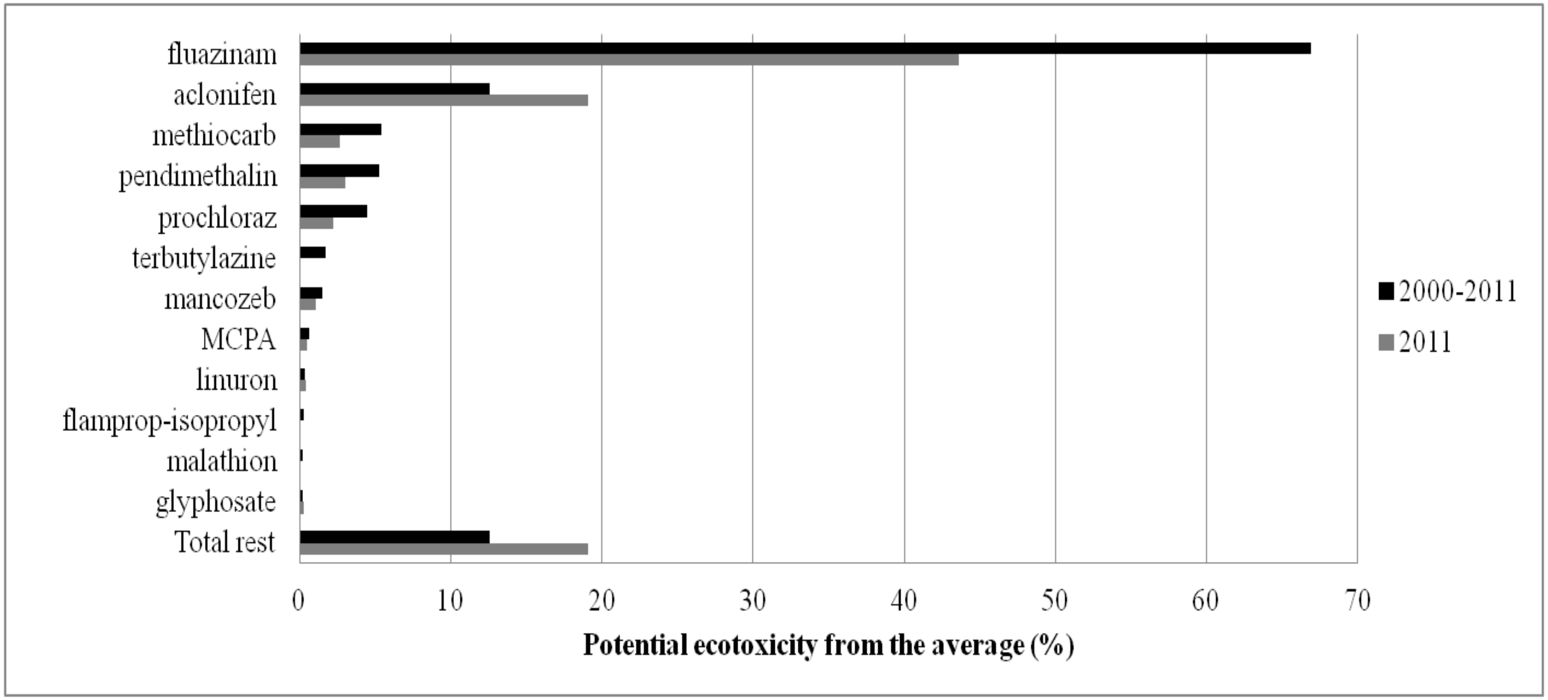

Figure. Pesticide substances in order to affect the most of the ecotoxicity pressure (in CTUs). Values are average impacts of active ingredients per year over 2000-2011 in Finland (%). Rest means other characterized substances than these 12 substances mentioned in this figure.

Conclusions

Conclusions

- With this method the effects of high amount of different chemicals used in various ways (e.g. in specific geographical conditions) can be compared to each others.
  - ➢ **Changes can be done in risk evaluations and management** e.g. to exclude the most hazardous substances from the sales and replace them safer ones or to change methods in the agriculture towards to more environmental friendly way
  - – A tool can be used in product chain improvements or consumer risk communication

Conclusions

- The first priority in the usage of this LCA approach is to identify environmental impacts of single hazardous PPPs and according to that to develop environmental management of plant protection and, if needed, build up restrictions which are properly directed to causes of impacts.
- Different LCA impact categories and other methods for studying the actions in produced plant materials should also be evaluated to obtain more realistic environmental effects in a field system and agriculture.
- Impacts induced by PPP usage are only one part of the total environmental effects in agriculture. More studies are needed in order to obtain a picture and conclusions for the environmental problems and changes in actions taken in agriculture in the EU and globally.

Acknowledgements

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  - SYKE: Ph.D. Mattila T. and Ph.D. Porvari P.,
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  - PesticideLife: a coordinated Life+ project of MTT 2010–2013 “Reducing environmental risks in use of plant protection products in Northern Europe”
  - SysIndex: a strategic project of MTT 2013-2016

    “Development of streamlined indicators in order to intentify and close down resource cycles and to improve dynamic sustainability of the food system”

Please read also our article:

Räsänen K., Mattila P., Porvari S., Kurppa S., Tiilikkala K. 2015. Estimating the development of ecotoxicological pressure on water systems from pesticides in Finland 2000-2011". *Journal of Cleaner Production 89 (2015) 65-77*. Available at http://www.sciencedirect.com/science/article/pii/S0959652614011792#

Thank you!

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