Sophie Mentzel[1], Claudia Martínez-Megías[2], Andreu Rico[2], Merete Grung[1], Knut Erik Tollefsen[1], and Jannicke Moe[1]

1 Norwegian Institute for Water Research
2 IMDEA Water Institute

Using a Bayesian network model to predict effects of pesticides on aquatic community endpoints in a rice field – a southern European case study

- **We propose a probabilistic approach to risk estimation incorporating temporal and spatial variability in risk estimation of pesticides using a Bayesian Network**
- **We use the Bayesian network as a meta-model that links the inputs and outputs for a process-based exposure model (RICEWQ) and a probabilistic case-based effect model (PERPEST).**

Background

- In the Mediterranean, climate change (CC) may affect the fate, transport and distribution of pesticides in aquatic environment (Noyes et al., 2009)
- Probabilistic approaches are recommended for risk assessment to account for uncertainty in pesticide exposure under future scenarios (Carriger & Newman, 2012; Mentzel et al., 2021)
- The goal of this study was to develop a model that offers a transparent way to estimate effects of pesticides on various aquatic taxonomic and functional (community) level.

Approach

We developed a Bayesian network (BN) as a meta-model using outputs from two prediction models:

- **RICE Water Quality (RICEWQ) model -** simulates chemical mass balance and aquatic exposure in rice paddies (Waterbourne Envirnomental Inc, 2011; Karpouzas & Capri, 2006), and
- **Predicts the Ecological Risks of PESTicides (PERPEST) model -** simulates pesticide effect to various taxonomic groups using an existing database for micro and mesocosm studies (Van den Brink et al., 2002)

Concept model:

- RICEWQ was run for all scenarios (climate condition - 2008, 2050, & 2100, and dosage applied - baseline & baseline+50%), for each a exposure concentration distribution was derived (Fig. 1).
- The effect concentration and prior probabilities for each of the taxonomic groups was determined by the PERPEST model (Fig. 2 & Fig. 3).
- BNs are constructed for three different pesticide types commonly used in the study area "Albufera national park" near Valencia (Spain): azoxystrobin (fungicide), MCPA (herbicide), & acetamiprid (insecticide) (Fig. 3).

Results

The BN model can derive outputs for the effect on each of the pesticide specific taxonomic groups. The displayed example shows the effect on insects by acetamiprid (Fig. 4) :

- It can be expected that insects are affected with a probability of 22 %, and slightly affected with a probability of 18 % (Fig. 4a).
- The likelihood of an effect on insects is true with approx. 30% and false with approx. 70% (Fig. 4b).

An assumption can also be made for the effect on functional groups (Fig. 5). We can compare the effect of acetamiprid on the different taxonomic groups (Fig. 5a):

  - Macroinvertebrate are predicted not to be affected with a likelihood of almost 100 %.
  - Insects, macro-and microcrustaceans, have higher probability to be affected with a likelihood of 25-30% .
- The probability for there being an affect on any of the taxonomic groups of the functional group of invertebrates is false with approx. 25 % and true with approx. 75%.

Furthermore, the functional groups of the different pesticide types can be compared (Fig. 6):

- It can be observed that the likelihood for there to be an affect on the plant community is lowest for acetamiprid with approx. 98%, and
- highest for MCPA with approx. 60%.
- Invertebrates have highest probability to be affected by azoxystrobin and lowest by acetamiprid (under climate conditions for 2008).

Future perspectives

- Future efforts will aim to incorporate more scenarios such as other crop types, application patterns and climate projections to derive a more realistic pesticide risk assessment.
- We aim to carry out an effect assessment of the intentional mixtures to address cumulative risk of complex environmental mixtures.

References

Noyes, P.D. et al., 2009. https://doi.org/10.1016/j.envint.2009.02.006
Carriger, J.F. & Newman, M.C., 2012. https://doi.org/10.1002/ieam.268
Mentzel, S., et al. 2021. https://doi.org/10.1002/ieam.4533
Karpouzas, D.G. & Capri E., 2006. 10.1007/s10333-005-0027-1
Van den Brink, et al.(2002). https://doi.org/10.1002/etc.5620211132

Bayesian network input information

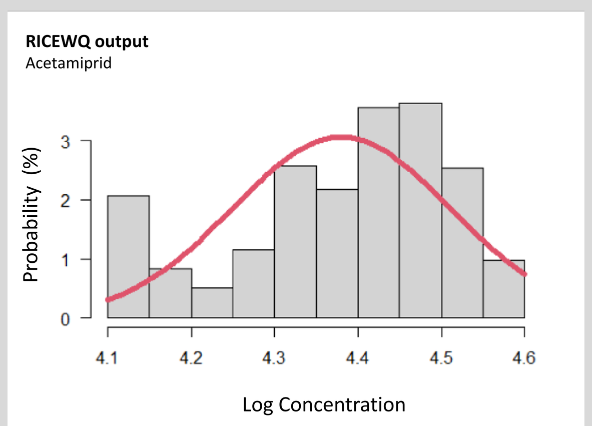

Figure 1 Example RICEWQ model output, for each scenario a distribution is derived and used as input for the exposure module of the BN.

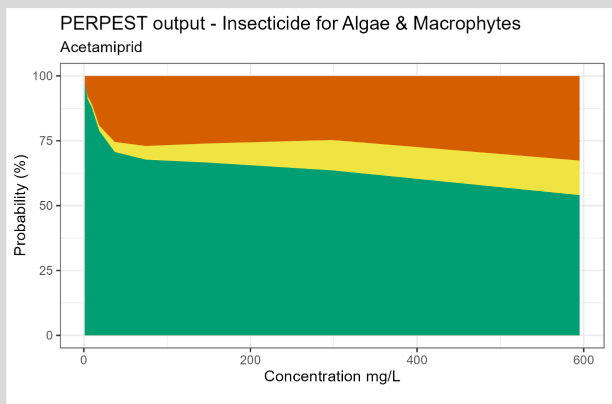

Figure 2 Example PERPEST model output, for each taxonomic group a gradient was derived and used as input for the effect module of the BN.

Parameterized model for an insecticide

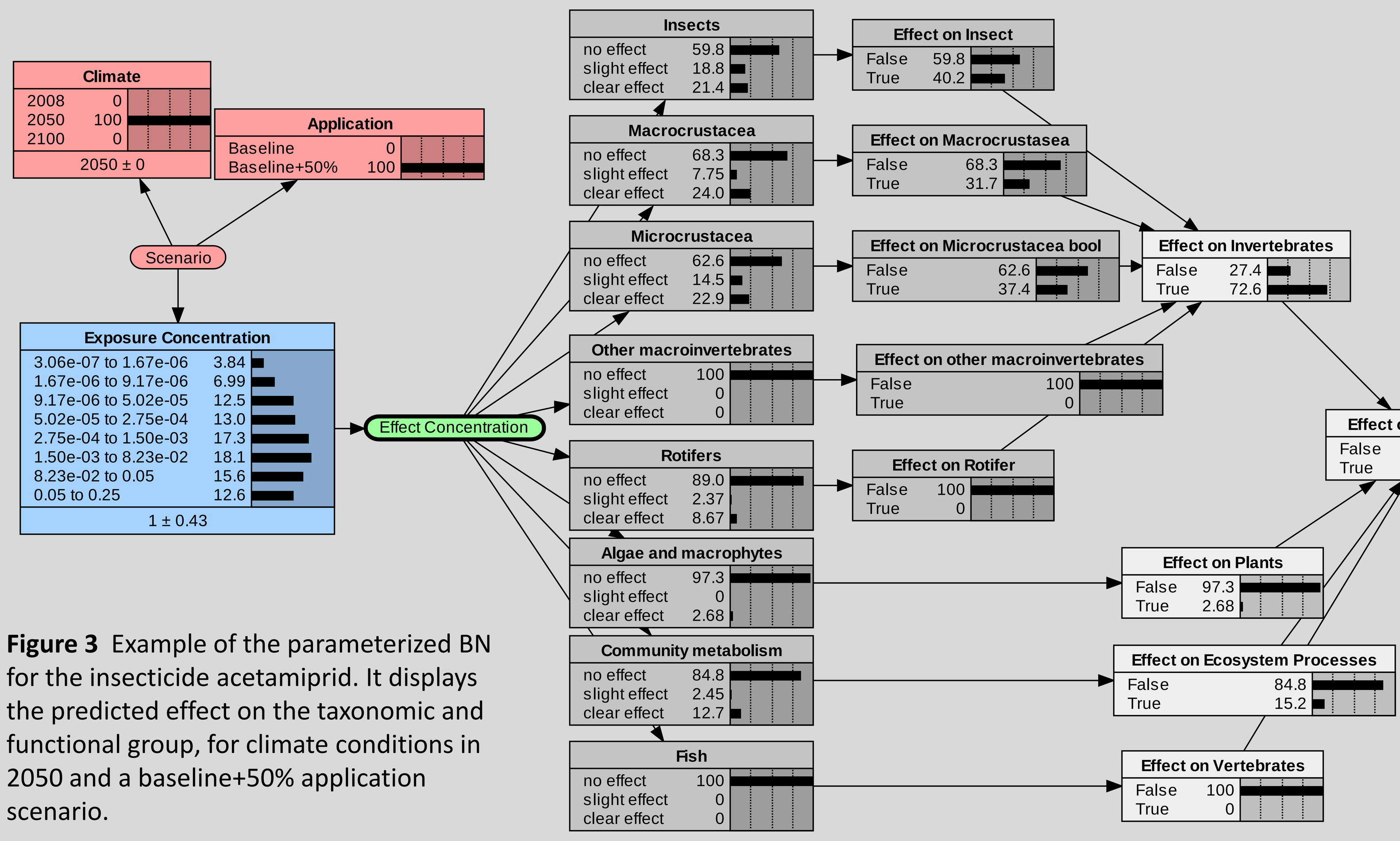

Figure 3 Example of the parameterized BN for the insecticide acetamiprid. It displays the predicted effect on the taxonomic and functional group, for climate conditions in 2050 and a baseline+50% application scenario.

Aggregation of the effect on taxonomic group

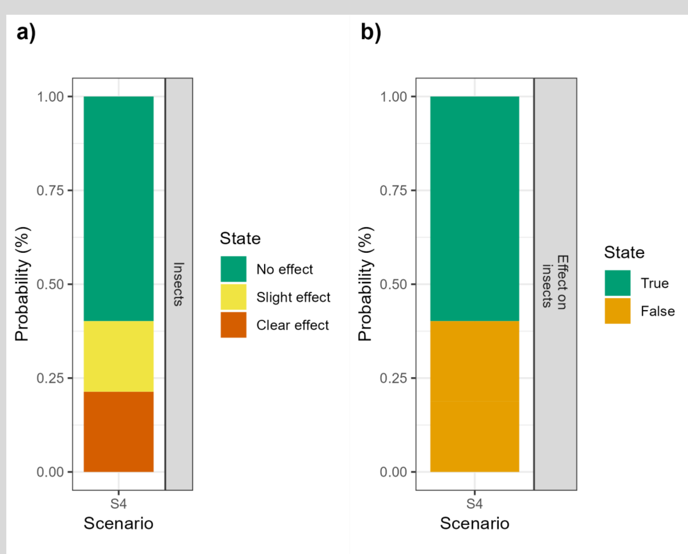

Figure 4 Example of the predicted effect on insects by acetamiprid for a specific scenario (a) and summarizing boolean node output displaying whether or not an affect of the pesticide can be assumed (b), for climate condition in 2050 and a baseline+50% application.

Aggregation of the effect on taxonomic to functional group

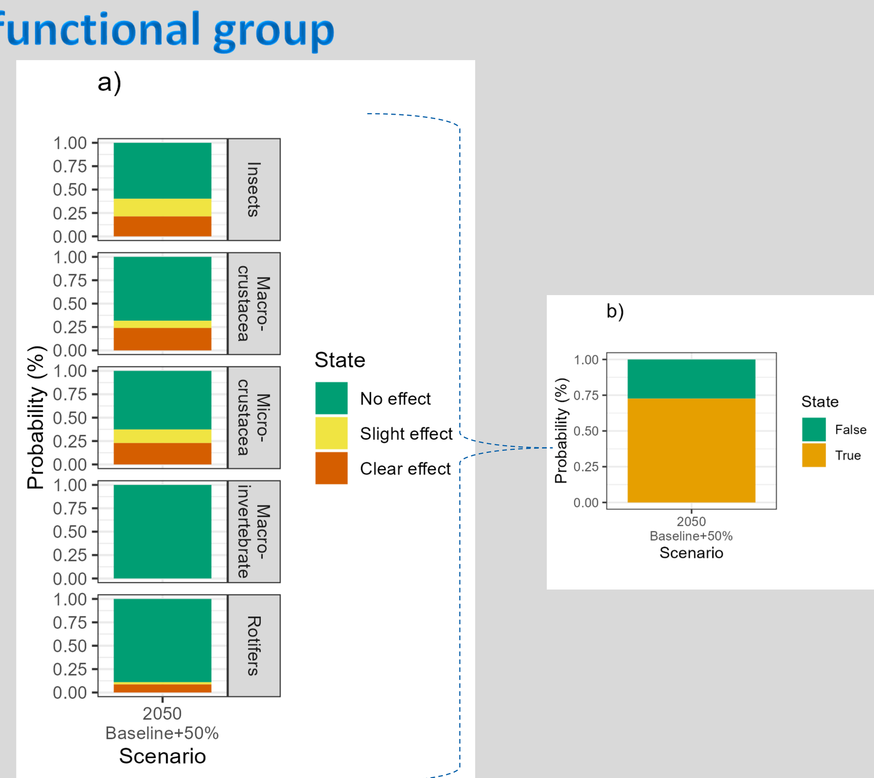

Figure 5 Example of the predicted effect of the insecticide on the taxonomic groups (a), that are considered in the functional group "Invertebrates" (b), for climate conditions in 2050 and baseline+50% application.

Comparison of the effect on functional groups /communities

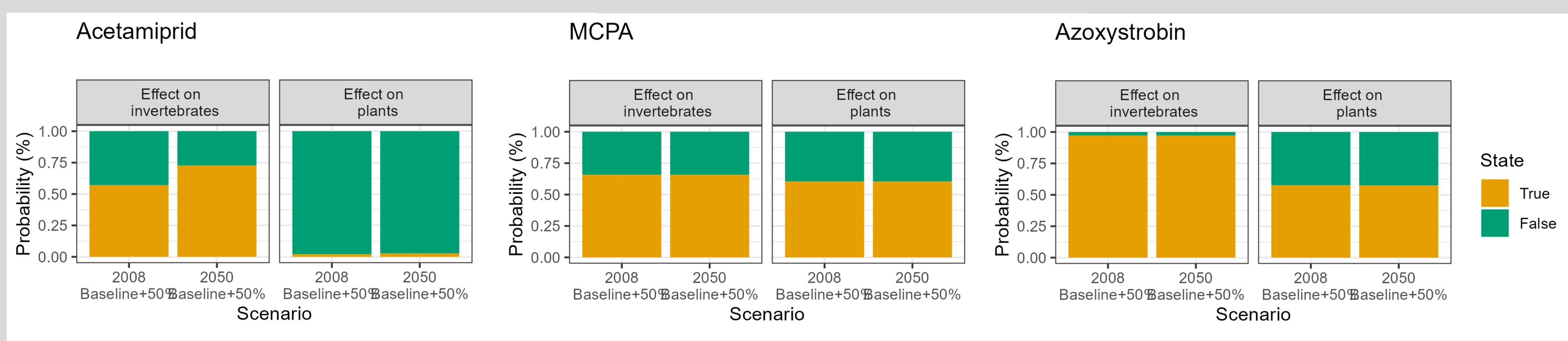

Figure 6 Examples of the predicted effect on the functional groups invertebrates and plants for the three selected pesticide (azoxystrobin, acetamiprid and MCPA), for climate conditions in 2008 and 2050 and a baseline+50 application

Contact info:
Norwegian Institute for Water Research (NIVA), Økernveien 94, 0579 Oslo, Norway
Email: som@niva.no

Acknowledgments

This research was funded by ECORISK2050, which has received funding from European Union's Horizon 2020 research and innovation program under the grant agreement No. 813124 (H2020-MSCA-ITN-2018). The CICLIC project, funded by the Spanish Ministry of Science, Innovation and Universities (RTI 2018_097158_A_C32), and the Talented Researcher Support Programme - Plan GenT (CIDEGENT/2020/043) of the Generalitat Valenciana. K. E. Tollefsen was funded by NIVA's Computational Toxicology Program (www.niva.no/nctp).