Ecotoxicological Risk Assessment of Pesticide Considering Different Geographical Scales and Evolution in Time

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In agricultural landscapes, biodiversity is affected by several factors. The widespread use of pesticides is one of the most important and needs to be assessed in order to reduce the level of impact. The potential aquatic and terrestrial ecosystems at risk are related to pesticides' pathways of distribution and their environmental fate. Within ALARM, a GIS-based methodology to assess the potential risk for aquatic and terrestrial (e.g., Barmaz et al., this atlas, pp. 218f.) ecosystems at several scales of assessment was developed.

Performing a risk assessment for biodiversity is a difficult task because it covers several issues and most of them suffer from a lack of crucial information. Several indicators have been developed to assess some aspect of biodiversity on the national, international or global scale but they often do not cover the complexity of the problem. This work represents an attempt to develop a tool for biodiversity risk assessment that integrates approaches and results coming from different disciplines (Ecotoxicology, Landscape Ecology, Hearth Sciences).

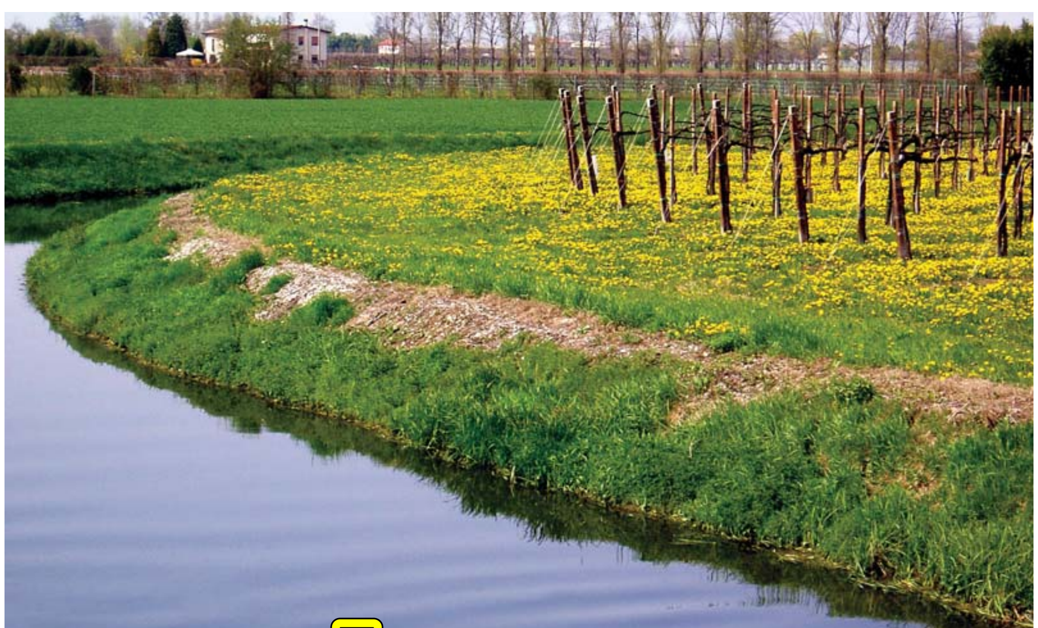

Figure 1. Meolo River basin.

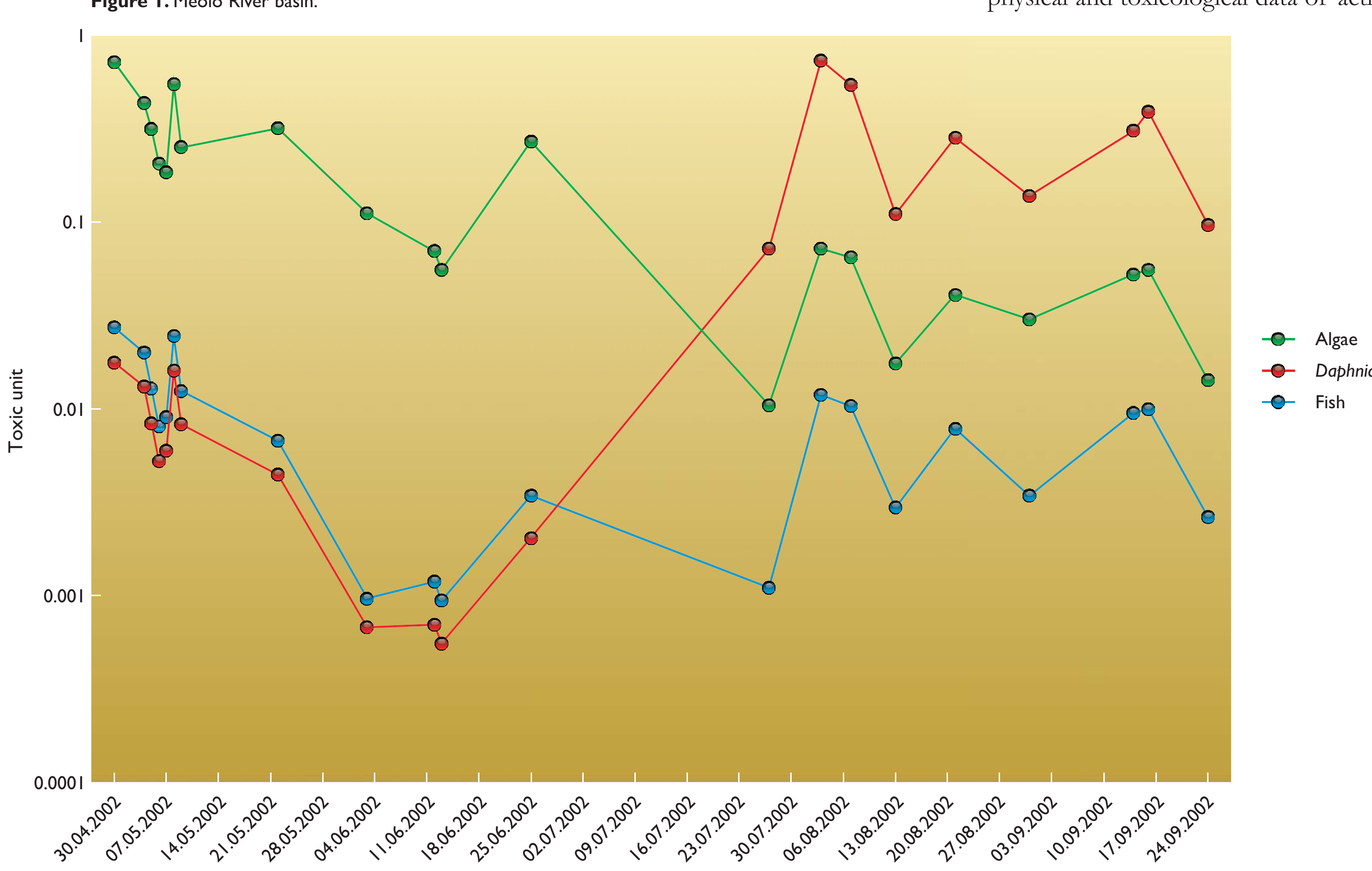

Figure 2. Toxicity for Algae, *Daphnia* and Fish of mixture of all pesticide applied in all crops in the Meolo River basin.

The methodology is based on an integration of databases, algorithms for pesticide exposure evaluation, risks indices, landscape's patch analysis using Geographical Information System for managing models' input data and results in a distribution over the area studied. Molecular properties, such as chemical-physical and toxicological data of active ingredients, and environmental characteristics, such as land use, crop distribution, landscape elements are managed for the elaboration and development of realistic application scenarios.

The methodology allows the user to calculate exposure and ecotoxicological risk indices for the main organisms representative of aquatic and terrestrial ecosystems. The use of GIS allows the user to account for the spatial variability of input data and output results (Sala 2008).

The steps towards an ecotoxicological site-specific risk assessment for biodiversity may be listed as follows

- identification of the problem and development of a conceptual model (emissions source, routes of exposure, potential targets) to achieve a scenario definition, possibly with a DPSIR scheme;
- landscape characterisation and selection of the scale of assessment;
- selection of suitable models to assess exposure;
- development of georeferenced and non-georeferenced databases of input parameter information for the selected model;
- site-specific exposure assessment according to different methodologies suitable for application in different environmental systems: aquatic, terrestrial hepigean (main targets: beneficial insects and birds), terrestrial hypogean; It requires the evaluation of both aquatic and terrestrial ecosystem, providing a specific assessment;
- effect assessment, performed using deterministic or probabilistic approaches depending on data availability; both approaches can be based on general (toxicity data on standard bioindicators) or site-specific (data on organisms representative of the community, function/structure of the ecosystem) information;
- potential risk characterisation, comparing exposure assessment with toxicological data; the assessment can be based on TERs (Toxicity Exposure Ratio), considering representative species, or on SSD (Species Sensitivity Distribution) where applicable;
- characterisation of exposed ecosystem: qualitative/quantitative ecological and landscape characterisation (faunistic vocation, distribution of living organisms, community structure, potential quality, actual quality) useful to determine vulnerability and sensitivity of the exposed ecosys-

tem. It will be based on approaches such as the Habitat Suitability Index, a numerical index that represents the capability of a given habitat to support a selected species. These models are based on hypothesised species-habitat relationships rather than statements of proven cause and effect relationships. The results of HSI model represent the interactions of the habitat characteristics and how each habitat relates to a given species. Indices of Landscape Ecology, useful to assess habitat fragmentation and shape of the landscape patch capable of affecting biodiversity are also applied;
- site-specific impact assessment, in terms of the risk posed by the stressors in the studied environment;
- experimental validation of results.

Aquatic ecosystems

In most recognised risk assessment procedures, the approach is based on the evaluation of chemical-physical and toxicological parameters, applied to more or less standardised scenarios where the territory, at different scale levels (local, regional, continental), is described without taking into account the spatial variability of data. This is the case for the European Technical Guidance Document (TGD) on risk assessment of chemicals and also the procedures required by European Directive 91/414EC on plant protection products.

The EU Water Framework Directive (WFD) requires the development of site-specific tools and indicators for river basin management, promoting the ecological protection of surface water and assessing the deviation of the ecological status from reference conditions in terms of:
- quality of the biological community;
- hydromorphological characteristics;
- chemical characteristics.

The result of a GIS-based procedure to assess ecotoxicological site-specific risk to aquatic ecosystems is presented (Verro et al. 2002). The Figures **3**, **4** and **5** illustrates the step of the evaluation: from predicted environmental concentration (Figure **3**) to risk index (Figure **5**) related to a certain quality of the exposed environmental system (Figure **4**), and a certain level of risk (Figure **5**).

The application of this methodology, and its further implementation (e.g., with meteo-climatic provisional scenarios, with temporal evolution of stressors, with socio-economic assessment), could represent a useful tool in order to combine and optimise provisional risk assessment for biodiversity supporting policy development.

A case history is described, referred to the application of the methodology at different scales (from field to regional) in order to underline the flexibility of the site-specific approach. An example of pesticide risk assessment for biodiversity is presented. The results allow comparison of active ingredients in order to draw a classification of the environmental sustainability of their use, to protect ecosystems and to evaluate vulnerability related to landscape elements.

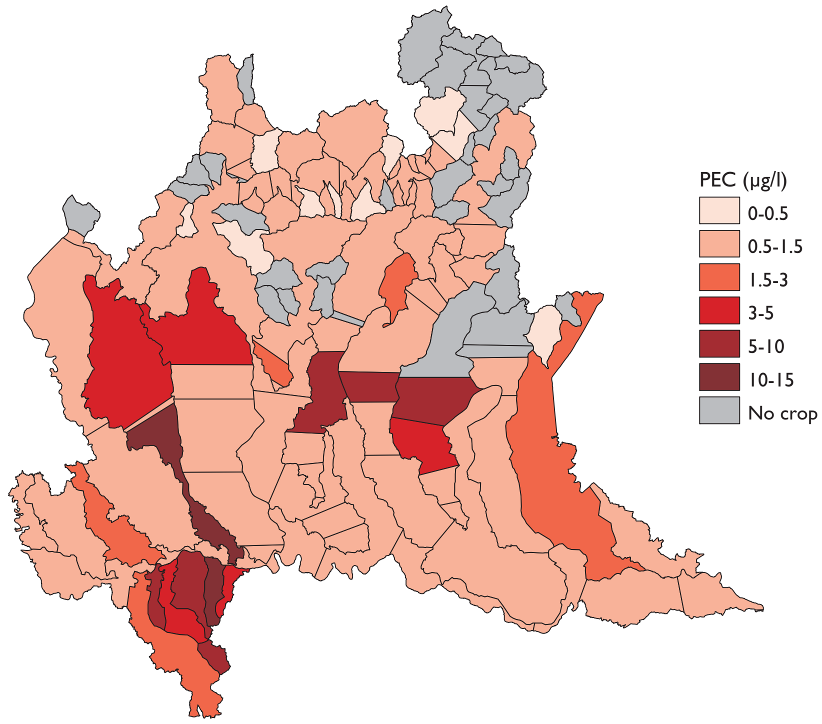

Figure 3. Predicted Environmental Concentration.

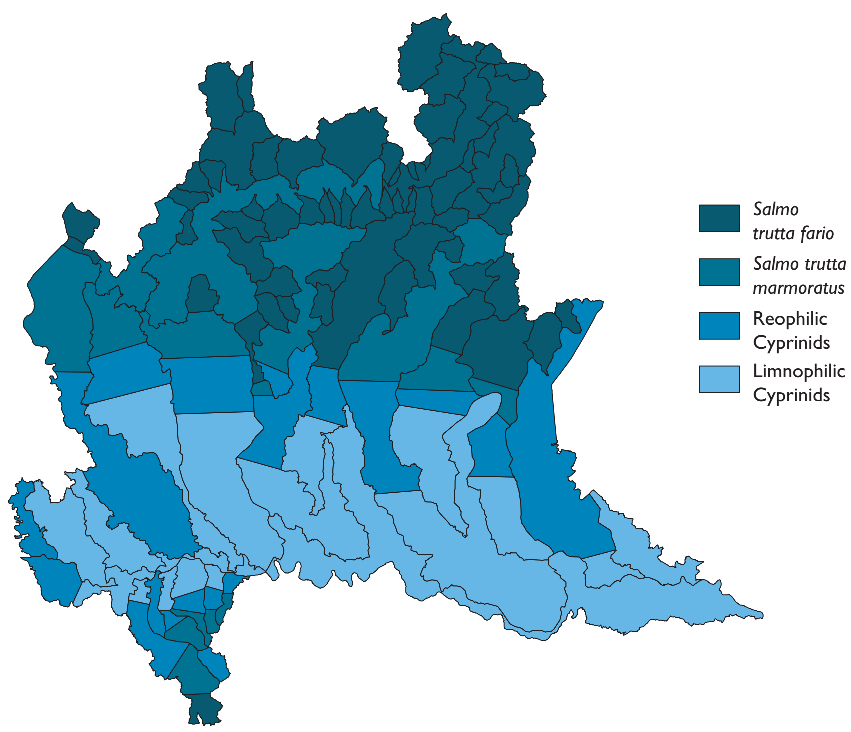

Figure 4. Potential environmental quality.

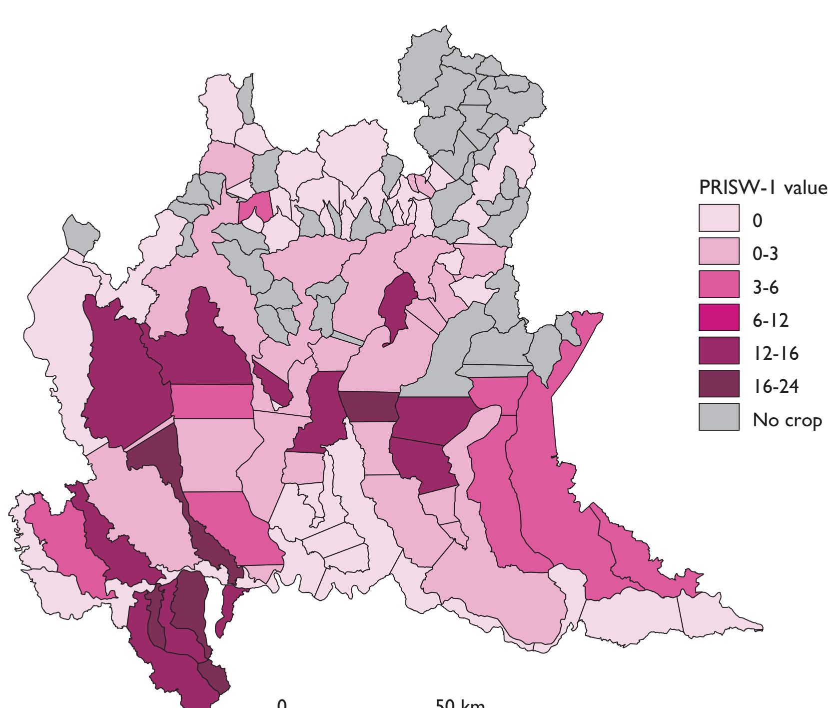

Figure 5. Risk index.

Mixture assessment

In natural ecosystems, biological communities are never exposed to individual stress factors or to individual potentially dangerous chemicals. In particular, in agricultural basins, surface waters contain complex mixtures composed of all the chemicals applied to the different crops grown in the basin and at different times of the growing season.

The composition of the mixture, as well as its toxic potency, is very variable as a function of the application dates of pesticides, of their persistency and physical-chemical properties. At each rain event, all pesticides present in soil, as residues of all applications prior to the rain, may reach surface water through runoff.

An example of time course of pesticide mixture risk over time in an intensive agricultural area (Meolo River basin, northern Italy) is shown in the Figure **2**, where the effects on the aquatic community are calculated for all the 54 active ingredients applied to all the crops present in the basin. The response to the mixture is calculated by applying the Concentration Addition (CA) approach, that is based on the principle of additivity of the mixture components. The CA approach tends to overestimate mixture potency, but it has been demonstrated that it represents a realistic worst-case for estimating mixture potency.

The toxic potency of the mixture is expressed as Toxic Units ($TUs = \Sigma\ Ci/EC50i$) for the indicator organisms assumed to be representative of the aquatic community (algae, *Daphnia* and fish). The risk to the different components of the biological community changes with time. In spring the mixture is highly dangerous to algae, due to herbicide application, mainly to pre-emergence herbicides applied to maize. Insecticide applications start in July and this produces a sharp increase of the risk to crustaceans. Herbicide risk decreases due to degradation of chemicals applied in spring. (Verro et al. 2007)

Reference

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Verro R, Calliera M, Maffioli G, Auteri D, Sala S, Finizio A, Vighi M (2002) GIS based System for surface water risk assesment of Agricultural Chemical. 1 Methodological Approach. *Environmental Science & Technology* 36: 1532-1538.

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