SIXTH FRAMEWORK PROGRAMME

FOOTPRINT

Mitigation strategies to reduce pesticide inputs into ground- and surface water and their effectiveness – a state-of-the-art review

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(on behalf of FOOTPRINT partners)

Introduction

- The contamination of water bodies with agricultural pesticides can pose a significant threat to aquatic ecosystems and drinking water resources.
- However, the risk for the aquatic community or for human health can often be substantially reduced by appropriate measures.
- Mitigation of pesticide inputs into water bodies includes both reduction of diffuse-source (runoff and erosion, tile drainage, spray drift, leaching to groundwater) and of point-source inputs (mainly farmyard runoff).
- Little is known about the comparative efficiency of these risk reduction measures.

Objectives of the present review work

- estimate the efficiencies of the various mitigation measures at the farm scale for different combinations of pesticide properties, soil and climate,
- assess the effects at the regional/catchment scale due to the implementation of a given mitigation measure,
- assess the effects of realistic combinations of mitigation measures at regional/catchment scale,
- evaluate the mitigation strategies identified in the literature with respect to their practicability and cost-effectiveness, and recommend those considered both effective and feasible for implementation at the farm and catchment scale,
- provide recommendations for modelling (e.g. for implementation in the FOOTPRINT tools) using the identified reduction efficiencies.

Literature survey

- Roughly 180 publications directly dealing with or being somehow related to mitigation of pesticide inputs into water bodies were examined.
- Both original studies and reviews were most numerous for the input pathway runoff and erosion (n = 88). However, not all experimental studies were usable for quantitative evaluation.
- The majority of runoff experiments and reviews dealt with (vegetated) buffer strips. Most of them were edge-of-field buffers directly below a field or plot, while only few studies investigated riparian buffers, i.e. buffers along the banks of streams or rivers.

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Publications examined dealing with or related to mitigation (multiple counts possible)

	input pathway				
	runoff/ erosion	drainage	leaching	drift	point sources
original studies (experiments)	68	17	12	22	11
original studies usable for quantitative evaluation	27	4	0	14	7
reviews	19	4	2	6	1
other	1	1	2	4	4

Studies investigated for the input pathway runoff and erosion (multiple counts possible)

	mitigation measures					
	buffer strips	constructed wetlands	grassed waterways	tillage practice	ground cover	other
original studies (experiments)	21 (edge-of-field), 5 (riparian)	6	3	3	2	2
original studies usable for quantitative evaluation	14 (edge-of-field), 2 (riparian)	4	2	2	1	1
reviews	10	5	1	1		1
other	1			1		1

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Main results for runoff and erosion

> There are considerably more mitigation measures (not only literature) available for the pathways runoff/erosion and spray drift than for drainage and leaching.

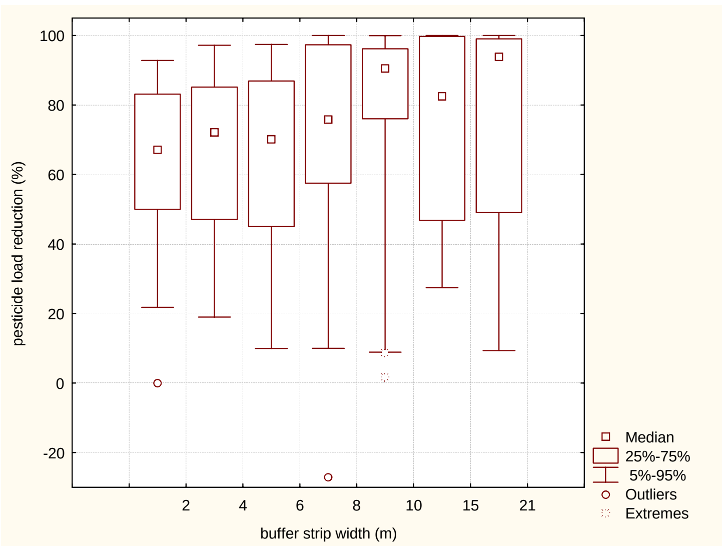
> Vegetated buffers strips:

- The effectiveness of grassed edge-of-field buffer strips for mitigating pesticide runoff and erosion inputs into surface water has been demonstrated in general. However, this effectiveness is very variable, and the variability cannot be explained by strip width alone.
- Riparian buffer strips are most probably much less effective than edge-of-field buffer strips in reducing pesticide runoff and erosion inputs into surface waters.

> Constructed wetlands are promising tools for mitigating pesticide inputs via runoff/erosion and drift into surface waters, but their effectiveness still has to be demonstrated for weakly and moderately sorbing compounds.

> Subsurface drains are an effective mitigation measure for pesticide runoff losses from slowly permeable soils with frequent waterlogging (but they lead to contamination of SW as well).

Pesticide load reduction efficiency vs. buffer strip width, all data points (n = 277)



Main results for drainage and leaching

> Reported mitigation measures available for the pathways drainage and leaching are very limited in comparison to those available for runoff/erosion and spray drift:

- The effects of pesticide formulation, tillage operations and pesticide incorporation into the soil on pesticide losses via drainage and leaching are insufficiently known and at best unpredictable → not suitable for recommendation as mitigation measures
- This leaves rate reduction, product substitution and shift of the application date as only feasible mitigation measures for both pathways.
- Investigations in FOOTPRINT have revealed that shift in application dates does not necessarily result in decrease in losses and maximum concentrations.
- For drainage, the use of collection ponds for drain outflow seems a further possible alternative, but there are no experimental data available so far on their effectiveness.

Main results for spray drift

> There are many possible effective measures of spray drift reduction and also many possibilities of combining two or more measures.

> While sufficient knowledge exists for suggesting default values for the efficiency of single measures, little information exists on the effect of the drift reduction efficiency of combined measures.

> More research on possible interactions between different drift mitigation measures and the resulting overall drift reduction efficiency is therefore indicated.

Main results for point-source inputs

- Point-source inputs can be mitigated against by increasing awareness of farmers with regard to pesticide handling and application, and encouraging them to implement loss-reducing measures of "best management practice"
→ cf. FOOT-FS point source audit
- Information and advisory campaigns and trainings were successful and effective in most study catchments, but continuous effort is necessary to maintain farmer awareness and prevent backsliding.
- In catchments dominated by diffuse inputs at least in some years, mitigation of point-source inputs alone may not be sufficient to reduce pesticide loads/concentrations in water bodies to an acceptable level.

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Practicability of MM and recommendations for implementation in practice

- The literature reporting on the effectiveness of mitigation measures demonstrates that results in terms of reduction of contamination are very variable and can even be contrasting, depending on climate patterns and locations.
- Still, the need to put actions in place to decrease pesticide contamination requires the overall effectiveness of mitigation measures to be assessed.
- Tables 3-6 in our proceedings paper provide such an assessment on the basis of the literature examined.
Every listed mitigation measure is evaluated in terms of its effectiveness and its practicability (including cost-effectiveness)
→ "recommendable" or "non-recommendable".
- Not only the cost-effectiveness of a mitigation measure, but also its ecological benefit and other side-effects should be taken into account when deciding which mitigation measures are to be implemented in a given case.

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Example: Effectiveness and practicability of some mitigation measures against surface runoff and erosion

mitigation measure	pesticide load reduction effectiveness		practicability	recommendable for use as mitigation measure?
	at farm scale	at catchment scale	ease of implementation, further benefits, obstacles, additional costs, impact on farming systems, disadvantages, risks	
application rate reduction	≈ percentage of rate reduction	≈ percentage of rate reduction	easy to implement, less pesticide costs, possible risk of insufficient pest/weed/disease control	yes
shifting application to earlier or later date	potentially very high but very variable	potentially very high but variable	easy to implement, possible risk of insufficient pest/weed/disease control	yes
buffer strips at lower field edge	variable (low to very high)	high	easy to implement, maintenance necessary, loss of arable land area for the strip and thus of crop yield	yes
riparian buffer strips	low	very low	easy to implement, but trees grow slowly; high ecological and recreational value; possible increase of pest/disease pressure	yes

Recommendations for modelling

> Recommendations (incl. default values of pesticide load reduction efficiencies) for modelling the effects of the mitigation measures recommended in Tables 3-6 for implementing at the farm and/or catchment scale can be found in

Reichenberger S., Bach M., Skitschak A., Frede H.-G., 2007. Mitigation strategies to reduce pesticide inputs into ground- and surface water and their effectiveness; a review. Science of the Total Environment, Vol. 384 (1-3), pp. 1-35.

> The paper has just been published. Please contact me for a pdf copy.

Outlook

> The results of the present review work will be integrated in the three FOOTPRINT tools (FOOT-FS at the farm scale, FOOT-CRS at the catchment and regional scale, and FOOT-NES at national and EU scale) to recommend mitigation measures to reduce pesticide contamination of water resources, and to simulate their reduction effect.

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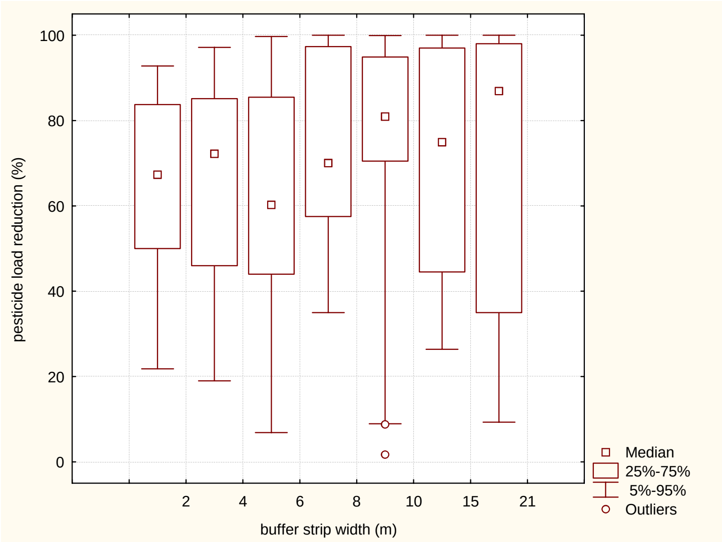
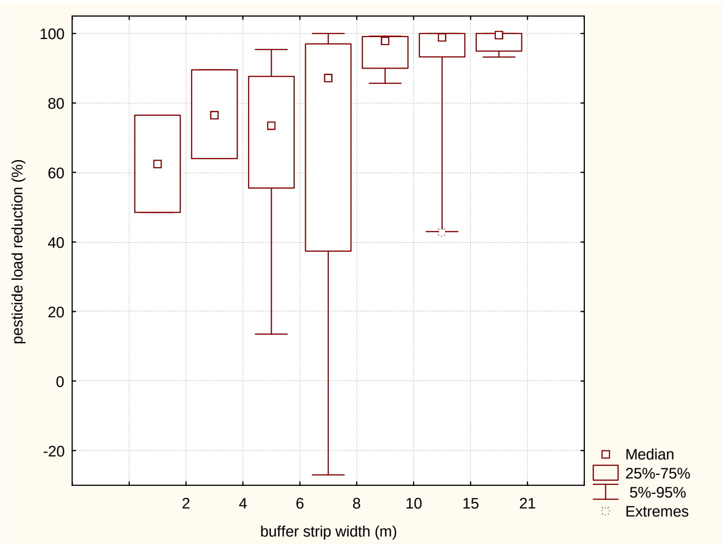
Pesticide load reduction efficiency vs. buffer strip width, water phase (n = 214)



Pesticide load reduction efficiency vs. buffer strip width, eroded sediment phase (n = 63)



Effectiveness at the catchment scale

- Assessing the effectiveness of mitigation measures at the catchment scale is generally difficult:
  - Studies systematically investigating the efficiency of mitigation actions at the catchment scale are usually lacking (except for monitoring studies to evaluate the effects of farmer information and stewardship campaigns).
  - Upscaling of efficiencies determined at field level to the catchment scale is not straightforward in most cases.
- “Catchment scale” in the context of this review means areas of ca. 1-1000 km^2.

Effectiveness at the catchment scale (2)

- While in edge-of-field assessments the field can be approximatively treated as a “point”, at the catchment scale additional spatial variability comes into play, e.g.:
  - different flow lengths and travel times from each field to the catchment outlet
  - different soils and land use
  - spatial variability of weather and climate (dependent on the size of the catchment).
  - spatial variability of pesticide application dates
- Moreover, the catchment’s topography and the position of landscape elements such as hedges, riparian buffer strips or grassed waterways decisively influence if and how much pesticides lost from a given field in the catchment finally reach a surface water body.

Effectiveness at the catchment scale (3)

> Deriving catchment scale efficiencies for given mitigation measures from their efficiencies at the field or farm scale is easier for “on-site” mitigation measures like edge-of-field buffers, subsurface drains or application rate reduction than for “off-site” measures like constructed wetlands, riparian buffers or grassed waterways:

- In both cases the efficiency at catchment scale will be proportional to the fraction of treated field area that is affected by the mitigation measure.
- But this area is much more difficult to determine for the off-site measures (for instance by flow concentration/accumulation calculations).