Agroecological practices for the management of drinking-water catchments in agricultural landscapes

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AGROECOLOGICAL PRACTICES FOR THE MANAGEMENT OF DRINKING-WATER CATCHMENTS IN AGRICULTURAL LANDSCAPES

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Abstract

With the intensification of agriculture over the past decades, yields have significantly increased, but at the cost of increasing and ongoing contamination of drinking-water resources. Over the past two decades different initiatives, action programmes, and policies in many countries throughout the world have been implemented to improve water quality in drinking-water catchments. But a real improvement in drinking-water catchments in agricultural landscapes can only be achieved if a landscape approach is implemented. This means that in order to establish a combination of different farming practices in large parts of the catchment, restoration or conservation of different seminatural landscape elements, and in very crucial areas strong extensification or even, if necessary, abandonment of agriculture. Among the most promising farming practices are different agroecological practices, as many showed reduced leaching or transfer of nutrients to groundwater or surface waters and decreased pesticide use. Examples are diversified crop rotations, intercropping, cover crops, cultivar mixtures, no or reduced tillage, direct seeding, split fertilization, agroforestry, biological pest control and integration of seminatural landscape elements around fields and at the farm and landscape scale. An example is provided in how to evaluate at landscape scale the needed establishment of seminatural landscape elements with the goal to improve conservation biological control in drinking-water catchments. Finally, some examples of water protection programmes are given which are based on paying farmers for certain measures or practices.

ONGOING CONTAMINATION OF DRINKING-WATER RESOURCES

Over the past four decades, with the intensification of agriculture, yields have significantly increased. Meanwhile, significant environmental problems have also emerged, such as the loss of biodiversity, pesticide contamination of soils and food and eutrophication of water bodies. Since the 1970s, one major issue has been the increasing degradation of water quality in drinking-water catchments as a result of increasing nitrate and pesticide concentrations (for example in Europe: European Commission, 2002; European Environment Agency, 2003). In particular, in different regions of the world, high nitrate contamination of groundwater resources has been ascertained (Li *et al.*, 2007; Lerner and Harris 2009; Alcott *et al.*, 2013; Gu *et al.*, 2013). In many regions in Europe, the nitrate concentrations are still very high in surface and underground water, despite the various European directives and programmes to address these issues (European Commission, 2011).

PROPOSED SOLUTIONS

In general, over the past two decades different initiatives, action programmes, and policies by either national, regional, or local authorities in many countries throughout the world have been implemented to improve water quality in drinking-water catchments (Bluemling and Horskoetter, 2007; Heinz, 2008; Grolleau and McCann, 2012; Alcott *et al.*, 2013, Grolleau, 2013; Nitsch and Osterburg, 2013; Barataud *et al.*, 2014). The proposed solutions applied to catchments, where agricultural land use dominates, are limitation of the use of agricultural pesticide and nutrient inputs by implementing adapted or new practices, including conversion of cropland to grassland; improvement of manure management and stocking facilities; purchase of agricultural land by the institution managing the catchment and, in certain cases, lending the land to farmers with fixed rules for agricultural practices; reforestation; exclusion of agriculture; or partially or completely converting to organic agriculture.

LANDSCAPE MANAGEMENT AND AGROECOLOGICAL PRACTICES

A real improvement in drinking-water catchments in agricultural landscapes can only be achieved if a landscape approach is implemented. This means the establishment of a combination of different farming practices in large parts of the catchment, restoration or conservation of different semi-natural landscape elements and, in crucial areas, strong extensification or even, if necessary, abandonment of agriculture. Among the most promising farming practices are different agroecological practices that have showed great potential for reducing leaching or transfer of nutrients to groundwater or surface waters and reduced use of pesticides (Figure 1).

Figure 1. **Different categories of agroecological cropping practices and their scales of application.**

SCALE OF APPLICATION OF AGROECOLOGICAL PRACTICE (↑)

LANDSCAPE SCALE	MANAGEMENT OF LANDSCAPE ELEMENTS › **Integration of semi-natural landscape elements at field, farm, and landscape scales**		
CROPPING SYSTEM SCALE	CROP CHOICE, SPATIAL DISTRIBUTION, AND TEMPORAL SUCCESSION › **Agroforestry** › **Cover crops** › **Intercropping and relay intercropping** › **Crop choice** › **Diversified crop rotations** › **Cultivar choice and mixture**	WEED, PEST, AND DISEASE MANAGEMENT › **Biological pest control** - *Natural pesticides* - *Allelopathic plants*	
FIELD SCALE	TILLAGE MANAGEMENT › **Direct seeding into living cover crops or mulch** › **Reduced tillage**	CROP FERTILIZATION › **Split fertilization** - *Organic fertilization* - *Biofertilizer*	CROP IRRIGATION - *Drip irrigation*

The practices contributing to reduce nitrate, phosphate, pesticides or herbicides concentrations in surface or groundwater in drinking-water catchments are indicated in bold and in blue

Source: Adapted from Wezel *et al.*, 2014

For example, at the field scale, these practices include no or reduced tillage, direct seeding, and split fertilization. At the scale of cropping systems these may include diversified crop rotations, intercropping (Figure 2), cover crops, cultivar mixtures, agroforestry and biological pest control. The integration of semi-natural landscape elements such as hedges, grass strips, shrubbery (Figure 2) around fields and at the farm and landscape scale allows not only for a contribution to reduced nutrient leaching or the transfer to surface waters, but also the enhancement of so-called conservation biological control. Through the maintenance or creation of habitats and over-wintering sites for various natural enemies, pesticide application can be reduced or stopped as these natural enemies can penetrate the fields and predate or parasitise the pests.

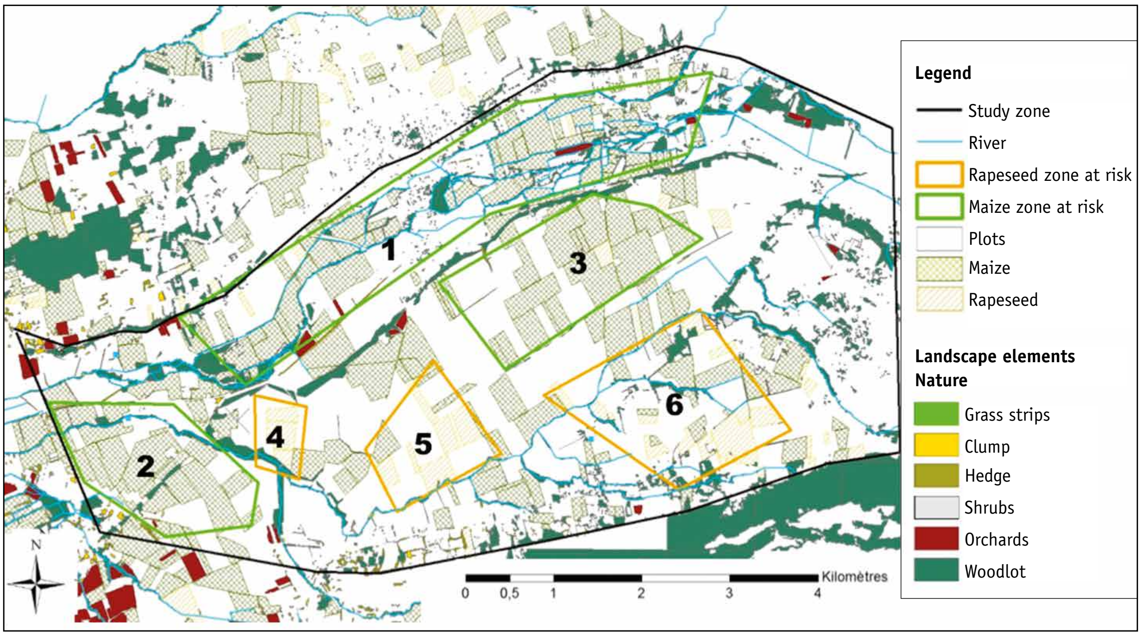
The way to implement these different practices needs to be adjusted in relation to local, regional, and national regulations and policy-framework conditions. Also local pedo-climatic and cultural situations in the catchment, farmers' constraints and possibilities for adapting or redesigning their systems also have to be taken into account. Thus, no universal solutions can be proposed. Farmers' voluntary adoption of practices should be encouraged, but experiences indicate that a combination of voluntary adoption, incentives and regulations may be more feasible.

The implementation of agroecological practices using a landscape approach is important, given the management of seminatural landscape elements in agricultural landscapes. The establishment of these elements is of great importance for improving conservation biological control in drinking-water catchments. Therefore, risk zones for groundwater contamination and for certain productions can be identified. For example, the risk zones in Figure 3 are characterised by shallow soils and short distance to groundwater, or dominance of high input, intensive maize or rapeseed production.

In respect to conservation biological control , if we now apply a buffer zone of, for example, 100 m around the existing seminatural landscape elements (Figure 4), areas can be delimitated where management would be most beneficial, e.g. in zones 3 and 5, which have a low number and cover of seminatural landscape elements (Figure 3). In the present example 100 m was taken, representing a distance over which more mobile natural enemies would be able to move. In contrast, less mobile natural enemies would normally not be able to move beyond a distance of 50 m or less.

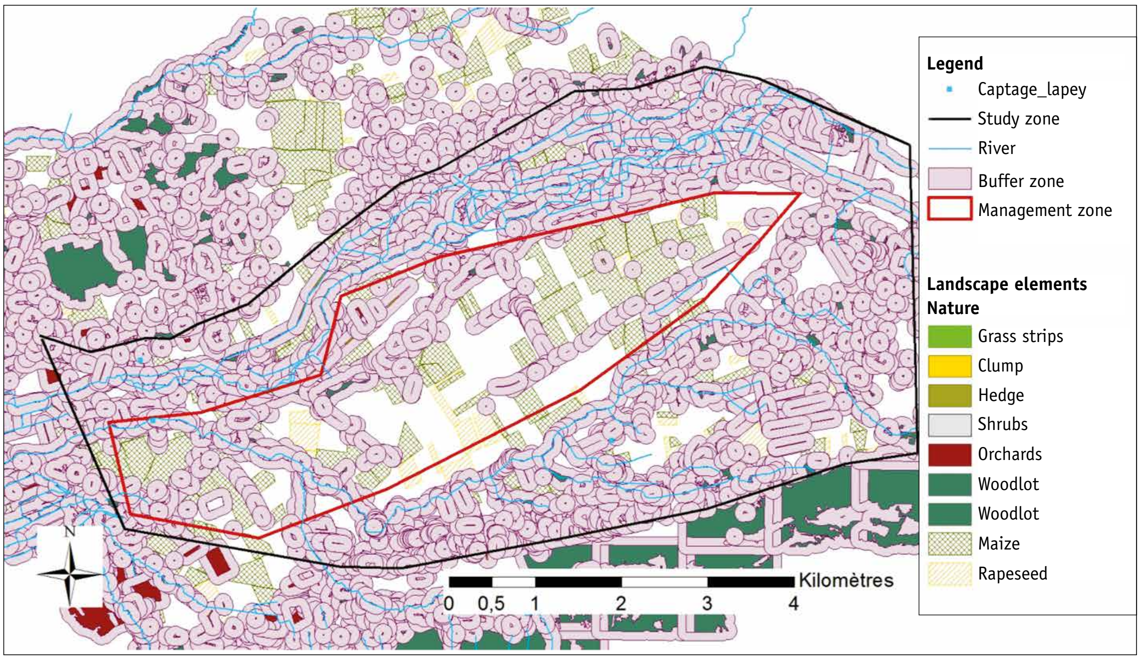
Figure 2. **Maize-clover intercropping (left) and semi-natural landscape elements in an agricultural landscape (right).**

Figure 3. **Delimitation of risk zones for groundwater contamination in a drinking-water catchment.**



Zones 1 to 6 are risk zones with shallow soils and short distance to groundwater, and/or dominance of high input intensive maize or rapeseed production.

Figure 4. **Application of a 100 m buffer zone around seminatural landscape elements to identify the management zone for the establishment of new landscape elements for improved conservation biological control.**



With the establishment of hedges, grass strips, or beetle banks in well-selected locations, this 'gap zone' can be reduced enormously and thus conservation biological control potentially improved. The selection of the different landscape elements to be implemented, and their associated plant species (e.g. different woody species in hedges), should be based on the evaluation of the principle pest in the target crops in the drinking-water catchment. Depending on the main pests, landscape elements and plant species should be selected that have greater potential for harbouring these pests' natural enemies.

WATER PROTECTION PROGRAMMES AND PAYING FOR IMPROVEMENTS IN WATER QUALITY

Most water protection programmes for drinking-water catchments in Europe are based on paying farmers for certain measures or practices (Bluemling and Horskoetter, 2007; Heinz, 2008; Grolleau and McCann, 2012; Grolleau, 2013; Nitsch and Osterburg, 2013; Barataud *et al.*, 2014). For example, to reduce nitrate pollution of surface and groundwater, agri-environmental measures have been frequently proposed over the past decade throughout Europe. An example of an agri-environmental measure that has been recently developed for cereal-dominated systems in France also includes different elements concerning reduced fertilization and crop protection inputs, crop diversification, and maintenance of woody infrastructure (Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, 2015). These and other measures or programmes that have been applied outside Europe (e.g. for the United States see Alcott *et al.*, 2013, Wezel and Francis, 2017) are almost exclusively based on paying for only the specific measure or action, without controlling its direct outcome. However, action-oriented schemes such as agri-environmental measures may not be efficient in changing farmers' practices and may fail to significantly restrict drinking-water pollution (Howarth, 2011).

A results-oriented payment approach is, so far, less developed for the conservation of water quality, in contrast to the management of biodiversity. With a result-oriented approach farmers are only remunerated if they achieve a certain result. So far, there is a relative rare example in Germany where a water protection programme has been successfully implemented, and a significant reduction in nitrate concentration has been achieved. Within a voluntary contract framework, which was developed together with the water supplier and farmers, farmers had the freedom to choose the best practice for managing their farmland in most areas of the drinking-water catchment (Wezel *et al.*, 2016). Upon successful achievement of a specific result, in this case a certain nitrate concentration in soils in autumn, farmers were provided with different payment levels depending on the nitrate concentration levels, to compensate for yield reductions. Using this approach, a very good drinking-water quality has been reached for many years, and this without any water treatment. The successful implementation was achieved in relation to the following factors: investment of significant amounts of money for high compensation and remuneration payments; different contract options; farmers' participation in the negotiation process for result-oriented payment contracts; involvement of 'outside' people and institutions in the negotiation processes; anticipation of starting a programme when nitrate levels were still far below legislated thresholds; and a political and legislative framework allowing decisions to be made directly by a water supplier.

CONCLUSIONS

With the intensification of agriculture over the past decades, yields have significantly increased, but at the cost of increasing and ongoing contamination of drinking-water resources. Over the past two decades different initiatives, action programmes, and policies in many countries throughout the world have been implemented to improve water quality in drinking-water catchments. But it became obvious that a real improvement in drinking-water catchments in agricultural landscapes can only be achieved if a landscape approach is implemented. This means that in order to establish a combination of different farming practices in large parts of the catchment, restoration or conservation of different semi-natural landscape elements, and in very crucial areas strong extensification or even, if necessary, abandonment of agriculture.

Among the most promising farming practices are different agroecological practices, as many showed reduced leaching or transfer of nutrients to groundwater or surface waters and decreased pesticide use. Examples are diversified crop rotations, intercropping, cover crops, cultivar mixtures, no or reduced tillage, direct seeding, split fertilization, agroforestry, biological pest control and integration of semi-natural landscape elements around fields and at the farm and landscape scale.

Besides the local pedo-climatic and cultural situations in the catchment, farmers' constraints and possibilities for adapting or redesigning their systems should be taken into account. Thus no universal solutions can be proposed. A voluntary adoption of practices by farmers should be favoured, but experiences indicate that a combination of voluntary adoption, incentives, and regulations could be feasible. Favourable policy framework conditions should be created to facilitate adaptation and adoption of farming practices.

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