Agronomic, environmental and social assessment of soil management strategies limiting herbicide application in Mediterranean vineyards, at the catchment scale

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1 Introduction

Maintaining and restoring the ability of agricultural soils to limit water and pesticides fluxes by overland flow is a particularly important issue in the Mediterranean wine growing area where overland flow has been shown to be a major factor of the contamination of water resources by pesticides. (Louchart et al., 2003). If the soil infiltration capacity is high, the soil exerts a buffering effect against floods, erosion and potential pesticide transfers. It is therefore important to identify soil management practices and their spatial distributions at the catchment scale that contribute to the preservation or restoration of soil infiltration properties throughout the year. Identifying these practices and their distribution implies to be able to assess their benefits and costs, ie: (1) the effects of those practices and of their spatial distribution on the soil's function to be preserved and (2) the constraints of implementation of these practices by the vine growers. The objective of the SP3A project was to identify and evaluate in Mediterranean viticulture, the soil management practices and their spatial distributions that limit the contamination of runoff waters by herbicides at the catchment scale while remaining acceptable by vine growers (Andrieux et al., 2014).

2 Materials and Methods

The study was carried out in the Rieutort catchment. This catchment covers 45 km², one third of which is covered by vineyards that are managed by about 150 full or part time vine growers. It is located north of Beziers, 90 km west of Montpellier, on the edge of the foothills of the Massif Central in France. The climate is Mediterranean, characterized by rainy autumns and springs and hot dry summers with heavy rainfall and strong inter-annual variability of rainfall (the average annual rainfall over 20 years is 690 mm with a maximum of 1585 mm and a minimum of 311 mm). Five major classes of soil can be distinguished including: (1) stony superficial soils, (2) clay soils of the transition zone between the northern slopes of shale and sandstone farther south; (3) sandstone soil; (4) fersiallitic soils; (5) sandy alluvial soils. Analysis of the quality of the water ressources in this catchment used for the production of drinking water showed an almost permanent contamination by herbicides and placed the catchment in the list of the 500 most threatened water drinking ressources in France according to the French Ministry of Ecology, Sustainable Development and Energie.

The scientific approach was in three steps. First, a group of scientists and local agricultural experts in viticulture identified adequate soil management strategies to reduce the use of herbicides across the catchment. These strategies define (i) targets in terms of herbicide use intensity at the plot and catchment scales, (ii) soil management practices to achieve these targets, while reducing the risk of runoff and (iii) spatial distribution rules of those practices according to the characteristics of the different plots of vines in the catchment. Second, an assessment of the environmental and production performances after implementation of these strategies was then simulated at the catchment and/or plot scales taking into account soil types and local climate. These evaluations were carried out for nine representative seasonal climate scenarios using an original chain of models. The chain of models was based on the use of (i) the DHIVINE decision model (Martin-Clouaire *et al*., submitted) to simulate timing of soil management operations at the plot resolution over the whole vine area, (ii) an extended version of the MHYDAS eco-hydrological model (Moussa *et al*., 2002) to simulate the evolution of soil surface features at the plot scale, and runoff and herbicide concentrations at the catchment outlet, (iii) the WaLIS water balance model (Celette *et al*., 2010) and a N balance model to simulate consequences of grass cover practices on yield reduction at the plot scale (Guilpart *et al*., 2014). Third, a survey of 31 full time vine growers in the Rieutort catchment was conducted in order to determine the current and possible future soil management practices and the dialogue network that structures the exchange of technical information among vine growers (Compagnone, 2014).

3 Results – Discussion

The environmentally friendly soil management strategies that were identified are given in Table 1. They consist in four main types defined according to a target in terms of a treatment frequency index (TFI). Two strategies aimed at no or rare herbicide applications whereas two others aimed at a medium rate of herbicide applications. All favoured, when possible, grass cover of the vineyard inter-rows.

The results of the environmental assessment of these strategies at the catchment scale (Table 2) showed the occurrence of herbicide concentration peaks at the catchment outlet exceeding the limit allowed for drinking water in the EU (0,1 µg/l) even for the strategy with a very small use of herbicides (Strategy 1b). Strategy 1a (no herbicide use) evidently respected the water quality requirements for drinking water, while the simulated herbicide concentrations for Strategy 2a and 2b were well above.

The agronomic assessment of water and nitrogen vine stress and consequences on grapevine yield at the plot scale (Table 3) highlighted the risks of decrease in grape production according to the spatial extent and duration of grass cover in the interrows. Permanent grass cover was shown to be possible only on deep alluvial soils whereas grass cover, even if limited to the winter period, was never possible on shallow stony soils due to the risks of water and nitrogen stressses. For the other soils types, grass cover is possible but there is a need to adapt its spatial and temporal extent to the annual climatic conditions.

Eventually, the analysis of the socio-technical networks in the Rieutort catchment revealed a collective ability of the wine grower community for technical change. Although the actual soil management techniques preferentially use herbicides for controlling weed, the community admit growers who apply alternatives practices.

Table 1. Description of the strategies selected to reduce the use of herbicides across the catchment. TFI: Treatment frequency index (number of full-dose treatments per hectare)

Strategy	Target of herbicide use intensity at catchment scale	Associated soil management practices
1a	TFI = 0	0 herbicide on the row (R) and inter-row (IR) – The soil is maintained by permanent grass cover (PGC) or winter grass cover (WGC) combined with tillage
1b	TFI ≤ 0,1	Idem strategy 1a with permission of post-emergence herbicide on the whole surface of very constrained plots (maxi 10 % on the vineyards area in the catchment)
2a	TFI ≤ 0,3	The IR are maintained by PGC or WGC combined with tillage. Permission of post-emergence herbicide on 1/3 of the plot area (≈ on the Row)
2b	TFI ≤ 0,4	Idem stratégy 2a with permission of post-emergence herbicide on the whole surface of very constrained plots (maxi 10 % on the vineyards area in the catchment)

Table 3. Environmental performances of the strategies considering herbicide leaching at the outlet of the catchment.

Simulated spatial distribution of practices and contamination by herbicide	Strategy			
	1a	**1b**	**2a**	**2b**
% of vine area maintained by PGC	28	28	27	27
% of vine area maintained by WGC and tillage	72	38	70	35
% of vine area maintained by WGC and herbicide	0	4	34	38
Average annual maximum peak of contamination (µg/l)	0	0.17	2.0	2.1
Maximum peak of contamination (µg/l)	0	0.33	3.4	3.5

Table 2. Acceptability of grass cover practices according to type of soil, at the plot scale. +: acceptable (the simulated yield reduction was under 15%); -: unacceptable (the simulated yield reduction was above 15%); ½ IR: 1 inter-row out of 2, ½ year: 1 year out of 2, 2/3 years: 2 years out of 3

Grass cover pratice	Type of soil				
	Allu-vial	**Fersial -litic**	**Sand-stone**	**Clay**	**Stony**
PGC all IR	+	+ 2/3 years	+ ½ year	-	-
PGC ½ IR WGC ½ IR	+	+	+	+ ½ year	-
WGC all IR	+	+	+	+	-

4 Conclusions

Reducing herbicides while maintaining grapevine yield is possible in the Rieutort catchment by favouring tillage and grass cover on the inter-rows, and possibly on the rows, of vine plots. But agronomic and environmental assessments highlighted a strong inter-annual variability of performances (yields and contaminations) due to the strong variability of soil and climate conditions in the catchment. Consequently, both assessments converge on the issue of introducing more temporal flexibility in the definition of strategies to reduce herbicide use as well as on the associated modalities of soil management practices associated. The results of each of these assessments should help vine growers to choose new strategies best suited to both the environmental constraints and the agronomical and economical constraints they face.

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