Ecological intensification of Mediterranean vineyards: effects on soil conservation and economic viability

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INTRODUCTION

Fertility is the ability of soil to provide a suitable environment for plant growth and food production. 40% of the Earth's terrestrial area is already appropriated for agriculture, and increasing food production must be achieved from existing agricultural land while reducing environmental impacts and conserving soil and water quality. This goal can be met by eco-intensification strategies that include improving input efficiency and managing correctly biogeochemical cycles is soil. Soil biodiversity cooperates to fertility through enhanced nutrient availability, prevention of pests and diseases, carbon sequestration and improvement of soil structure and water holding capacity.

Here, we present a successful case of ecological intensification in a Mediterranean vineyard, compared to two other vineyards managed under organic and conventional intensive strategies. Our aim is to show that there is no contradiction in the simultaneous pursuit of improving soil quality and biodiversity and maintaining production and economic gain.

MATERIALS AND METHODS

We studied three contiguous farms in Marzà (Girona, Spain) similar in geology, soil type (Haplic Regosols) and climate (mean annual T: 15.2 °C; annual rainfall: 703 mm) but differing in management. One farm is intensively managed (IN): tillage three times yearly, glyphosate and pesticides application and mineral fertilization. A second farm is being managed organically (OR) since 2007: no tillage, spontaneous grass cover mown twice yearly, residuals let to decompose on the site, and plagues controlled with Bordeaux broth. The third farm was intensively managed until 2015, when an ecological intensification strategy (EI) was adopted, ploughing was suppressed and cover crops were stablished; currently, the soil is decompressed yearly by air injection and humic acids and microorganisms are provided. Manure is applied as fertilizer. Fungi attacks are controlled with copper and sulphur, and harmful insects with pheromones (Fig.1).

In the spring of 2019, we stablished four sampling transects at each farm. At each transect, we buried four pairs of tea bags to study soil ability for mineralization following the Tea Bag method, and sampled soil (four samples per transect) for physical and chemical properties, respiration, functional biodiversity and matter fluxes through the trophic web.

Table 1. Soil properties in vineyards managed under ecological intensification (EI), organic (OR) and conventional intensive (IN) strategies.

		EI	OR	IN	Model (p)	EI/IN (p)	EI/OR (p)	IN/OR (p)
E. conductivity	$dS\ m^{-1}$	0,146 ± 0,02	0,081 ± 0,06	0,066 ± 0,01	0,013	0,011	0,069	ns
pH (1:2,5 H_2O)	-	7,1 ± 0,09	5,9± 0,08	5,9 ± 0,25	0,002	0,003	0,004	ns
Water content	%	1,3± 0,08	1,1 ± 0,1	0,8 ± 0,0	0,002	0,002	0,117	0,047
Bulk Density	$g\ cm^{3}$	1,36 ± 0,1	1,15 ± 0,02	1,64 ± 0,06	0,044	ns	ns	0,037
SOM	%	2,09 ± 0,27	2,39 ± 0,25	0,86 ± 0,15	0,001	0,002	ns	0,001
N (Kjendal)	%	0,12 ± 0,02	0,12 ± 0,01	0,06 ± 0,01	0,001	0,002	ns	0,001
P (Olsen)	$mg\ kg^{-1}$	39,1 ± 11,1	19,81 ± 3,8	7,3 ± 0,7	0,003	0,02	0,192	0,036
Ca	$mg\ kg^{-1}$	1498 ± 175	905± 162	739 ± 86	0,016	0,016	0,06	ns
Na	$mg\ kg^{-1}$	42,5 ± 2,5	39 ± 2,1	30,5 ± 1,9	0,0008	0,008	ns	0,037
K	$mg\ kg^{-1}$	251,2 ± 27,6	202,7 ± 18,7	69,5 ± 4,4	<0,0001	1E-04	ns	<0,0001
Mg	$mg\ kg^{-1}$	228,2 ± 30,8	167,5 ± 24,5	130,5 ± 14,9	0,074	ns	ns	ns
K (tea bags)	-	0,011 ± 0,001	0,114 ± 0,03	0,01 ± 0,00	ns	ns	ns	ns
S (tea bags)	-	0,235 ± 0,04	0,274 ± 0,08	0,211 ± 0,01	0,002	0,001	ns	ns
Plant roots	$g\ m^{-2}$	1,32± 0,3	2,37± 0,2	0,49 ± 0,18	0,02	ns	ns	0,018
Microbes	$g\ m^{-2}$	20,4± 2,9	28,3 ± 3,8	14,5 ± 3,2	0.005	ns	ns	0,004
Bacteria	$g\ m^{-2}$	7,3± 1,945	11,6 ± 2,6	6,2 ± 2,6	0,049	ns	ns	0,038
Fungi (living)	$g\ m^{-2}$	13,9 ± 2,4	16,6 ± 2,6	8,3 ± 1,1	0,068	ns	ns	0,055
Flagellates	$g\ m^{-2}$	0,02 ± 0,004	0,002 ± 0,00	0,001 ± 0,00	<0,001	<0,001	<0,001	ns
Amoeba	$g\ m^{-2}$	0,91 ± 0,39	0,11 ± 0,05	0,03 ± 0,01	0,004	0,004	0,038	ns
Ciliate	$g\ m^{-2}$	0,03 ± 0,02	0,0005 ± 0,00	0,001 ± 0,00	ns	ns	ns	ns
Total protists	$g\ m^{-2}$	0,9 ± 0,4	0,12± 0,05	0,03 ± 0,01	<0,001	<0,001	<0,001	ns
Fungi/ bacteria	-	6,7 ± 3,3	7,1 ± 5,2	9,4 ± 4,2	ns	ns	ns	ns

PRELIMINARY RESULTS

Management deeply affected soil quality (table 1). In the IN vineyards, soil was very poor in organic matter, N, available P, Ca, Na, K and Mg, with values significantly lower than in EI and OR. Soil physical structure was also worse in IN than in EI and OR, with higher bulk density and lower water retention capacity. The IN vineyards also were biologically poor, with low microbial and protozoa biomass. The OR and EI vineyards had similar physical quality, but electrical conductivity and pH were significantly higher in EI than in OR.

Our data show that ecological intensification of the agriculture can reverse soil organic matter and nutrient depletion in as little as four years and that the functional biodiversity that runs the soil metabolism responds positively to this type of management. In our vineyards, the adoption of organic strategies together with the use of light machinery, improved microbial inocula and intelligent water management also resulted in net gains in production and economic profit after three years of conversion compared with the period of intensive management (Fig. 2).

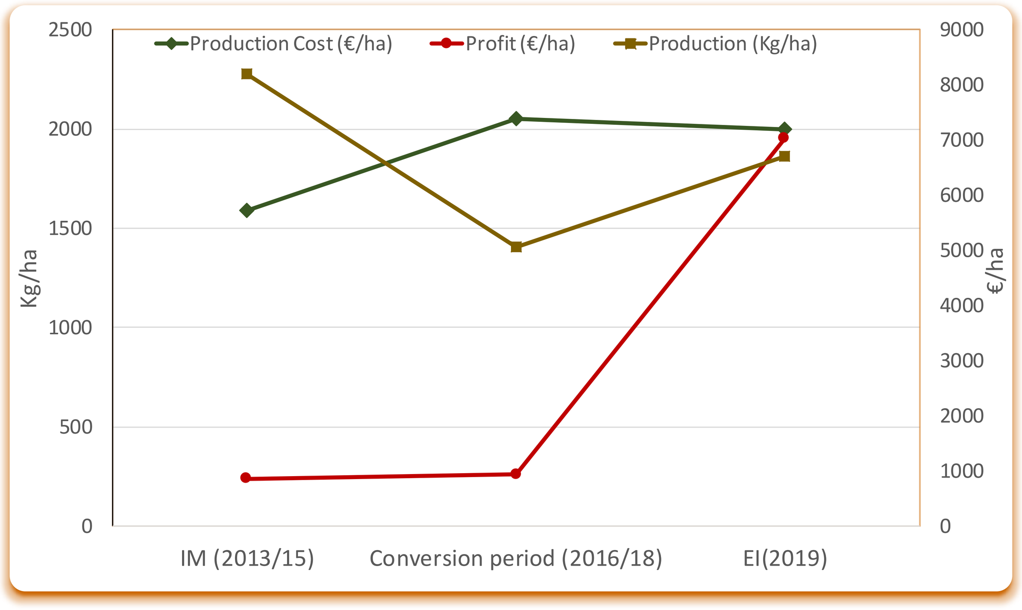

Fig. 2. Yield and economic profit in the EI vineyard during the transition from conventional management to ecological intensification

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