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Challenges and opportunities for increasing organic carbon in vineyard soils: perspectives of extension specialists

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Abstract. Locking soil organic carbon (SOC) is predicted to help mitigate the effects of climate change. Adoption of SOC sequestering practices in vineyards could contribute to this solution. In this study, we analysed perception of extension specialists. Our goal was to characterize current and favourable SOC-friendly practices and better understand the challenges at the farm level. To target the goal, we conducted 32 semi-structured interviews in both semi-arid and temperate-cold climate areas in France and in United States. We found that the single or combined practices of cover crop, organic fertilization, tillage reduction, grazing, agroforestry, mulching and herbicide use reduction are already implemented in both temperate-cold and semi-arid vineyards and should be further incentivized. We found economic, agronomic, educational, conflict of interest and structural challenges. The first barrier common in both countries and climate areas, was the cost of the practice. The second most important barrier in semi-arid regions is the potential negative impact of cover crop on yield. The next challenges were: (i) training of winegrowers to implement the practices; (ii) food safety in table grape associated with livestock grazing; (iii) climate for competition for water and nitrogen; (iv) planting density for agroforestry in Protected Designation vineyards and finally (v) availability of organic fertilizers withing or next to the farm. Greater emphasis on addressing these challenges is urgently needed to inform agricultural policies in both countries.

1. Introduction

The cultivation of grapes holds significant economic and cultural value in regions where climatic conditions support its growth [1]. Vineyards are among the most prevalent agricultural systems in various European nations [2]. In the United States, almost 2.2 million acres of grapes are grown, with over 6.4 million tons processed for wine in 2022 (the USDA agricultural census data is available). Vineyards are located on a range of soils worldwide, many of which can be characterized by low soil organic carbon (SOC) and substantial soil erosion [3]. Improving SOC can lead to improved soil health [4] as well as productivity and grape quality [5]. SOC is often reduced in vineyards where bare soil is maintained, whether it is through the intensive use of herbicides [7] or tillage in the inter-row [1] or under vines [6]. While the literature can provide data-based recommendations to grape growers on how to improve SOC in vineyards, there are a multitude of potential obstacles to immediate adoption of scientific recommendations, including lack of dissemination of research results to the industry, cost of practice adoption, etc. Additional, successful approaches and outcomes of SOC building practices are place based and context specific. The adoption of practices can be accelerated or slowed down by environmental, policy, socio-cultural or economic factors unique to a production region [9]. Temperate and arid climates also provide different management opportunities for SOC accrual. A survey of 506 French winegrowers suggested that adoption of practices to increase SOC is often limited to returning pruning residue to the soil to improve soil quality and agricultural productivity [8]. A survey of 16 American winegrowers suggested that more practices are adopted but large-scale adoption is blocked by potential economic risks and lack of information on how practices impact grape production [5]. It is therefore important to have coordinated research efforts across various wine growing regions to elucidate management opportunities for SOC in vineyards and some of the local levers and barriers to adoption.

In both the USA and France, grape growers partially rely on public or private technical assistance and extension specialists/agents to advise them on adoption of vineyard practices. Extension specialists often act as a bridge between researchers and growers –translating scientific knowledge into practical advice. Our objective was to explore through semi-structured interviews the perception of extension personnel regarding challenges and opportunities for improving SOC in vineyards in France and the USA in semi-arid and temperate-cold climates.

2. Material and methods

2.1. Material

2.1.1. France and United States as two case study

The surveyed area included the two main grape growing regions in the United States and in France. For each **country**, two climatic zones were investigated: temperate-cold climate zone and semi-arid climate zone (table 1).

Table 1. Studied vineyards contexts.

Country	Köppen climatic		Region
	zone	code	
France	temperate-cold	Cfb	Alsace, Burgundy, Champagne
France	semi-arid	Csa	Ardèche, Beaujolais, Hérault, Vaucluse
USA	temperate-cold	Dfa	New York, New Jersey, Pennsylvania
USA	semi-arid	Csa	California

2.2. Methods

2.2.1. Sampling of interviewees

Interviewees were extension specialist located in the 4 areas: semi-arid and temperate-cold French vineyards and semi-arid and temperate-cold American vineyards. 69 cases were identified with snow ball method [10]: at the end of each interview, we asked for more names of extension specialists. A total of 32 extension specialists was interviewed (n=8 for each of the 4 regions).

2.2.2. Data collection

We characterized perception of extension specialists regarding practices which are known to maintain and increase SOC in vineyard. One **survey** was conducted with a subgroup of extension specialists based on semi-structured interviews. Thirty-two extension specialists were surveyed.

Interviews were video calls transcribed during the interview and validated by the interviewee at the end of the video call.

The American interviews were carried out in June and August 2022 and the French interviews were carried in September and October 2022.

The **questionnaire** contained closed and opened questions, which addressed the major practices involved in maintaining soil organic carbon in vineyard.

Survey **responses** were anonymous and Institutional Review Board approval was given prior to the interviews and survey implementation.

2.2.3. Data analysis

We used **inductive content analysis** method and open coded our interviews into key themes emerging from the interviews [11]. According to the method, we grouped the answer in main categories: eco-environment, policy, production/practices, socio-cultural and socio-economic. For each main categories, generic categories were created. No statistic done on the presented data.

3. Results

3.1. Current practices

We found seven SOC-favourable practices already implemented in France and USA, both in semi-arid and temperate-cold climates (fig. 1). All extension specialists reported that changing management of cover crop, management of organic fertilization, reduction of tillage, increasing grazing, increasing hedges or agroforestry, increasing mulching inter row and reducing herbicide use are already implemented by some winegrowers and should be further incentivized.

In both countries and climate zones, adoption and management of cover crops to increase the level of organic carbon in vineyard soils was cited by all but one of the respondents (31/32). Organic fertilization is the second existing practice that can have a positive impact on the organic carbon of the vineyard soil, mentioned by 26 of the 32 extension specialists as a current practice. The lowest number of positive respondents to this query was in USA-temparate-cold, perhaps because organic matter content of the soil is already quite high, often in the range of 3-5%.

In semi-arid climate regions, 62% of US extension specialists mentioned reduction in tillage as an additional practice while agroforestry and hedges (25%), and grazing (12%) were mentioned in the French context.

In the temperate cold climates, US extension specialists mentioned reducing tillage (3/8), straw mulch inter row (2/8) and reducing herbicide (1/8) as major practices whereas, agroforestry and hedges (3/8), grazing (1/8), straw mulch inter row (1/8) and reducing tillage (1/8) were emphasized by extension specialists in France.

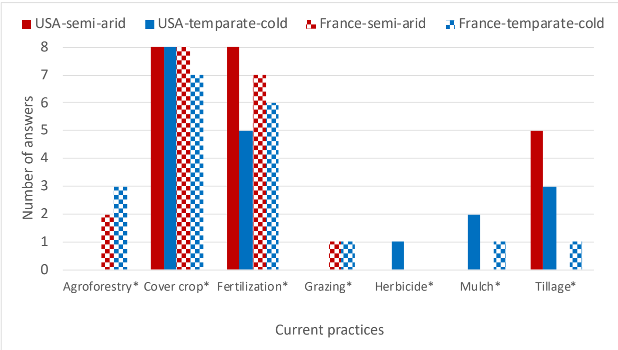

Figure 1. Seven current practices identified to maintain or increase SOC. *: Increase hedges or agroforestry; Increase/maintain/diversify/till cover crop; Use compost/organic fertilization/return pruning residue; Increase grazing; Reduce herbicide; Straw mulch inter row; Reduce/eliminate/change tillage.

3.2. Barriers to practices

Barriers to practice adoption were similar among regions, although fewer respondents from France-temperate-cold region specified challenges. We found economic, agronomic, educational, conflict of interest and structural challenges to practice adoption (fig. 2).

69% of the extension specialists mentioned the cost of the practice as the first challenge to adoption of SOC-favourable practice, and the risk of negative impacts on yield. The cost of adoption of new practices was cited by the greatest number of respondents (22/32) as a barrier to practice adoption, with cost of both equipment and labour cited as a potential problem, as well as costs of inputs such as seeds and specifically delivery of organic amendments. Equipment, labour, worktime, alternative, seeds, organic fertilizer availability were cited by 7/8 as a barrier to a new practice in USA-semi-arid region.

An agronomic challenge identified specifically was concerns over competition of cover crop with vine vigour. We gathered information about cover crop management to address some of these challenges such as cover area, diversity of spontaneous and sown species and termination practices in the different regions. Education and training of winegrowers needed included knowledge to implement the practices at the field scale and systems redesign at the farm scale. Conflicts of interest included potential food safety issues associated with livestock grazing, particularly in table grape production.

There are three structural barriers which cannot be modified by practices. The first structural barrier identified included climate driving competition for water and nitrogen, which is a big issue with the actual change in climate. Vineyard and climate characteristics were cited by 11/32 as a barrier to new practice adoption, particularly in the French regions, accounting for 8/16 of responses. The second structural barrier is the availability of organic fertilizers next to the farm. Finally, the last identified barrier was reglementary and included planting density for agroforestry in Protected Designation vineyards. Responses were likely linked to the regulation associated with terroir and the AOC system present in a lot of vineyards in France.

Interestingly, only two respondents cited ‘no challenge’ to maintaining or increasing SOC. These responses were both in USA-temperate-cold, where high organic matter soils predominate.

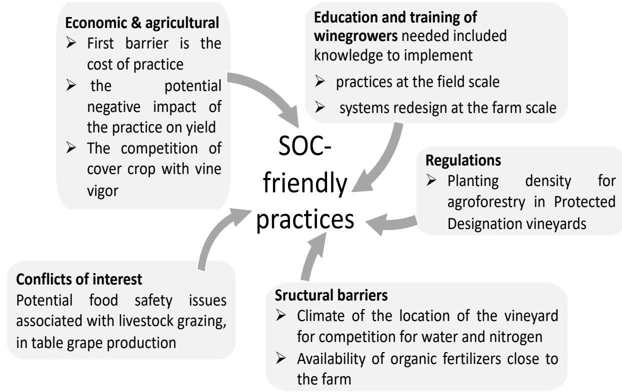

Figure 2. Diversity of barriers to adopt SOC-friendly practices in vineyard.

4. Conclusion

Our results demonstrated current practices to prioritize for incentives for soil organic carbon preservation in both United States and French vineyards. Our case studies demonstrate that SOC-friendly practices already are implemented in vineyards and locks to increase of SOC-practices are identified as next steps to increase SOC sequestration in vineyards. Greater emphasis on addressing the challenges to adoption of SOC-favourable practices is urgently needed to inform national and regional agricultural policies in both countries.

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