Academy of Wine Business Research
Hochschule Geisenheim University
8th International Conference
June 28th – 30th, 2014 | Geisenheim, Germany

A Sustainable Response to the Requirements of the Aware Consumer: The Case of the New Drought-Resistant Rootstocks

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◦*Purpose:* Faced with the impact of climate change, consumers are showing increasing interest in sustainable wine production.
This paper proposes an evaluation of whether the innovative solution represented by new generation rootstocks (i.e. M4), compared to those traditional (i.e. 1103 P), within the ambits of

Italian viticulture, constitutes an efficient response to tackle climate change.
◦*Design/methodology/approach:* The project analyzed the expediency of the investment through a cost-benefit analysis, considering resilience as theoretical approach (cross-cutting theme). The analysis considers two important wine-growing areas in Italy, the North-East and Sicily. The spatialization of the drought-prone areas was done by means of an *ad hoc* multiple linear regression model. On the basis of these results, and given the performances of the rootstocks considered, three irrigation levels were considered in relation to three temporal scenarios of pedoclimatic evolution (status quo, 2030 and 2050).
◦*Findings/practical implications:* The economic results demonstrate the higher earnings of the M4 rootstock in comparison with that traditional for both areas and for all the irrigation regimes considered. The financial analysis registers a clear advantage from substituting the traditional rootstock with that innovative. In general, for the wine-grower the advantage is greater in the non-irrigated vineyards and with a limited irrigation regime and decreases with the increase of the discount rate. In the two areas analyzed, the land that would be planted with innovative rootstocks is about 130,000 hectares in the status quo scenario and could prospectively (i.e. 2030 and 2050 scenarios) be extended to those not currently exposed to the risk of drought, reinforcing the resilience of the vineyards that presently need irrigation. The adoption of the rootstocks can lastly determine important social benefits in relation to a reduction in water use.

Key words: Sustainability Viticulture, Vitivinicultural resilience, Innovative rootstocks, Cost-benefit Analysis.

PREFACE

The wine market is characterized by an increasing competition among suppliers (Pomarici et al., 2012; Mariani et al., 2014). Competitors have to offer wines with very high value for money, being consistent with the evolving values of consumers and adapting to the changes in production environment. In this perspective two major issues can be identified: increasing interest of consumers for sustainability and the growing impact of climate change on agriculture, which is determining an enlargement of areas exposed to drought risk, particularly in Mediterranean areas under vine. Therefore adaptation of viticulture to climate change and the discovering of paths to guarantee continuity of production with environmentally-friendly solutions are of particular importance. Indeed, as emerges from the most recent literature and the latest European policy guidelines, these topics will assume increasing importance in the coming years. This subject has been tackled by the Ager Serres project. The project is composed by working groups from the Italian universities of Milan, Padova, UCSC, Turin and the Fondazione Enrico Mattei, CRA-VIT in Conegliano, CRA-ABP in Florence. The aim of the project is within the framework of the development of models of sustainability for Italian viticulture, with special reference to aspects related to abiotic stresses. Among these, those relative to the impact of climate change and the effects this might have on the availability of water are of particular significance. In this regard, viticulture in Italy is currently limited by the availability of root stocks with characteristics suitable for abiotic stresses. This is the context in which the Ager Serres project was set up. The project has analyzed four innovative root stocks (series M) in different areas, which have been evaluated in different climatic and economic scenarios. The aim of this paper is to briefly illustrate the organisation of the Ager-Serres project and to present the results of the first economic evaluation of the convenience of the use of new rootstock resistant to drought in two very different geographical contexts in Italy: North-East and Sicily, in the south.

The paper is organized as follows. The first part introduces the subjects and objectives. The second part presents the scenarios of evolution of the Italian wine-growing areas and the methodology applied to evaluate cost and benefits of the use of new rootstock (materials and methods). The third part reports the results and the last section contains main conclusions.

1.INTRODUCTION

In the last decades the emergence of increasingly pressing challenges that the agricultural sector has had to face, such as climate change, food security, efficient use of resources, production methods and ecological planning, protection of rural areas and biodiversity (OECD, 2011) has led to increased attention to innovation in agriculture. Nowadays, innovation is particularly needed to adapt to input and output market developments, and changes in resource quality and availability (OECD, 2012). Schumpeter (1934) defined innovation as primarily a combination of existing knowledge that is economically more feasible or more efficient than the previous way of doing things. An innovation according to Rogers (1983) is “an idea, practice or object that is perceived as new by an individual or other unit of adoption”. While diffusion is seen as “the process by which an innovation is communicated through certain channels over time among members of a social system”. For many years innovations were seen as products developed by scientists, disseminated by advisory bodies and then put into practice by farm businesses (Sunding and Zilberman, 2001).

More recently, this view has been challenged by findings that depict agricultural innovations as social processes dependent on farm-level knowledge, rather than the simple adoption of a new product or technique (Abadi Ghadim and Pannell, 1999).

The Ager Serres project is on the subject of the sustainability of the wine-growing sector. It is inserted in the framework of the innovative guidelines promoted by the European Commission that, with Horizon 2020, are aimed at pursuing development based on research, innovation and sustainability (European Commission, 2011).

According to the research group of the Intergovernmental Panel on Climate Change, the climatic variations that have affected the Planet will continue in the next decades (IPCC, 2007; Matthews, 2008). Given the vulnerability of the wine-growing ecosystem (Jones, 2007; Ashenfelter, Storchman, 2010), the importance emerges of identifying sustainable solutions that allow the probable effects of climate change to be tackled and to safeguard the production capacity (Ostrom, Cox, 2010; Niles, Lubell, 2012) of viticultural systems.

Within this long-term prospective, the property most closely linked to the idea of sustainability is resilience (Perrings, 2001; Holling, 1973; Folke et al., 2002; Milestad and Hadatch, 2003; Spielman et al., 2011). Among the scientific concepts currently used in sustainability science, resilience[1] is probably one of the most relevant (e.g. Brand, 2009). Indeed a growing number of case studies have revealed the close connection between resilience, diversity and sustainability of social-ecological systems (e.g. Folke *et al*., 2002). Currently, two main definitions of resilience can be retrieved: the first, generally referred to as engineering resilience, gives to the term the meaning of the time required for a system to return to an equilibrium point following a disturbance event (see among others Holling, 1996), in the second approach, called ecological resilience, it is seen as the capacity of an ecosystem to resist disturbance and still maintain a specified state (e.g. Gunderson and Holling, 2002). In other words, it is how to persist through continuous development in the face of change and how to innovate and transform into new more desirable configurations (Folke, 2006).

In viticulture, in the adoption of innovations aimed at sustainability (Rogers, 2003), this capacity is utilizable by the producer if the economic and environmental benefits outweigh the inherent coAsts. These approaches are spreading in different countries, both in the New World (United States, Australia, New Zealand, South Africa, Chile, Argentina, etc.) and in Europe (France, Spain, Italy, etc.). In 2002, California launched the Sustainable Winegrowing Program (SWG) aimed at promoting the adoption and continual improvement of sustainable practices throughout the wine-production chain (California Winegrowing Alliance, 2014; Haden et al. 2012). In crop management, these consist of the rationalization of the use of water, energy use, calculation of the emissions and sequestration of greenhouse gasses, etc. There are economic benefits for the producers committed to sustainable practices, such as a reduction in production costs, improvement of the product quality, greater attention to environmental regulations, etc. (Hillis et al., 2010; Lubell et al., 2011, Hoffman et al., 2013). On the Californian model, McLaren Vale Sustainable Winegrowing Australia (MVSWGA) was presented in 2009, which considers an improvement of wine-growing sustainability in relation to the environmental impacts and market forces (McLaren Vale Grape, Wine & Tourism Association, 2014). Since 1997, New Zealand wine-growers have developed a programme named Sustainable Winegrowing New Zealand that involves the implementation of a model of environmental best practices from the vineyard to the winery. The approach involves an improvement of the guarantee of product quality in relation to consumer requirements, with the aim of obtaining and marketing environmentally-friendly wines (Sustainable Winegrowing New Zealand, 2014; Gabzdylova et al., 2009). In Chile, the certification of sustainability, implemented in 2011 by the *Consorcio I+D Vinos de Chile*, differs in the systemic approach to sustainability (Hansen 1996; Daly, 1996), by a greater accent on the criteria of social equity (orange chapter). Since the early 2000s, the *Comité interprofessionnel du vin de Champagne* has encouraged, at the *vignerons* and *maisons*, the development of a sustainable viticulture model based on four key areas of intervention. Among these, particular importance is placed on the measures to tackle climate change and the reduction of environmental risks (Moncomble, 2012; Comité interprofessionnel du vin de Champagne, 2014). In Spain, the Wineries for Climate Protection initiative follows the same line of thought, proposing itself as international reference for the wine industry, in the search for the best practical solutions to meet the challenges of climate change in viticulture (Spanish Wine Federation, 2014).

The arrival of *Phylloxera vastatrix* in Europe in the second half of the 19th century (Planchon et al., 1868) determined profound changes in viticultural research and techniques, which have led to the constitution of biform grapevines in which the root apparatus (root stock) is of American species and the epigeal part (grafted variety) is *V. vinifera*.
In Italy, the constitution of the *Consorzi Antifillosserici* (1901) and the scientific input of numerous researchers and technicians, including Guttuso - Fasulo (1906), Paulsen and Gibertoni (1908), Coceani (1908), Dalmasso and Sutter (1915), Dalmasso, Cosmo and Dell'Olio, (1929-1931), and private companies, have allowed the diffusion of the grafting technique for the reconstitution of vineyards with American roots. Some of the root stocks selected then were resistant to drought (e.g. 140 Ruggeri, 1103 Paulsen, etc.). However, over time, they have suffered technical erosion and have become increasingly less adequate in terms of climate change (sudden stresses, extreme events, etc.). There is thus a need for new root stocks that can maintain the sustainability of wine-production in conjunction with the new scenarios. Under the technical-productive profile, they must satisfy the requisites of yield, quality and sensorial profile; while from the economic point of view, they are evaluated in terms of earnings, cost-benefit flows and resilience.
Given the nature of the project, it is considered useful not just to be limited to an economic analysis, but also to produce results in terms of resilience, as this can more appropriately capture the aspects of sustainability. In this context, the aim of the research is the evaluation of the introduction of an innovation in Italian viticulture, by means of a cost-benefit analysis, and utilizing resilience as the key to the results (cross-cutting theme). The project involved two areas of Italy particularly important and renowned for wine production: the North-East characterized by sparkling wines and still reds; the South and the Islands, typified by white wines and still reds.

2. MATERIALS AND METHODS

2.1. Data sources

The study compared one of the most diffuse grapevine rootstocks (traditional) with rootstock of the series M (innovative). The traditional rootstock (control) is 1103 Paulsen (*V. berlandieri* x *V. rupestris*). The innovative rootstock (M4), produced in the 1980s by the research group of the University of Milan (Scienza et al., 2001), is an interspecific cross between 106-8 [*V. riparia* X (*V. cordifolia* x *V. rupestris*)] and Resseguier n°1 (*V. berlandieri*) and is drought-resistant.
The behaviour of the root stocks was observed on Cabernet Sauvignon, an international variety, among the most 'plastic' and for this reason diffuse in many areas wine-growing areas in Italy and abroad. The experimental vineyards, cultivated with the traditional and innovative root stocks, were organized in a scheme of randomized blocks, which had the same training form (spurred cordon) and planting layout (0.8x2.4 m) and were cultivated with the same cropping technique as the traditional rootstocks. The data gathered on the principal quantitative (yield per plant in Kg) and qualitative parameters (°Brix, total acidity, anthocyanins, pH) regarded the years 2006-2012.
From the point of view of the analysis of the principal technical–productive parameters, the comparison between innovative and traditional root stocks denoted a series of benefits (Scienza et al., 2001) such as: a better grape quality, accompanied by lower vegetative vigour; increase of production in the presence of abiotic stresses; reduction (or elimination) of irrigation; reduction of interventions on the foliage (e.g. topping, etc.); reduction of some pesticide treatments (rot from *B. cinerea* and oidio); possibility of expansion of the vines in high-value zones (DOC/G) currently not planted due to the high production risk or high cultivation costs.
The economic/financial data was supplied by the RICA database of INEA, and validated, both by means of an investigation conducted on a sample of representative farms in the studied areas, and considering the judgements provided by experts in the wine-growing sector (Florio,

2002).
Three maps were produced of the drought restrictions for vine cultivation, one referred to the present time and the other two for the years 2030 and 2050.
Elaboration of the maps required the use of the following data:
- Land use (Corine land cover with a grid spacing of 100 m (De Jacher, 2012);
- Digital elevation model (DEM) with 100 m spacing;
- Soil Aridity Index with a grid spacing of 1,000 m (SAI, Costantini and L'Abate, 2009), that expresses the long-term mean annual number of days when the topsoil (first 50 cm of soil) is dry;
- Climatic geodatabase available on line from CIAT (http://www.ccafs-climate.org/data/) for 30-year mean periods, the 2030s (2020-2049) and 2050s (2040-2069). Specifically, the 2030 and 2050 mean annual temperature and rain were downloaded with the following condition: IPCC Special Report on Emissions Scenario (SRES) A1B; DELTA method; cccma_cgcm3_1_t47 model; resolution of 30 seconds (Ramirez et al., 2010);
- Pedological information, extracted from the Soil Information System of Italy (SISI, www.soilmaps.it, Costantini et al., 2013). SISI is a Spatial Data Infrastructure that stores geographical and semantic information about soils and soil forming factors, including climate, geology, relief and land use, at different scales. The database stores the soil data of 22,015 profiles. They are classified and georefenced soils and grouped in 1,413 soil type units (STU).
The method for the elaboration of the maps consisted of two steps.
First, the vineyards and the lands potentially available for vineyards were selected. They were agricultural areas lying below 800 m a.s.l. The drought level was then estimated through the calculation of the SAI. The SAI values were estimated following a multiple regression (Costantini and L'Abate, 2009) with long-term mean annual air temperature (Ta), total annual rainfall (R), and soil available water capacity (AWC).

$$SAI = 75.363 + 6.874 * Ta - 0.064 * R - 0.299 * AWC \quad (R2 = 0.55; P<0.001; n = 260) \qquad (1)$$

The estimations of SAI for the 2030s and 2050s were obtained applying (1) to the predicted Ta and R. A linear regression was used to spatialize the estimated SAI. The grid of the long-term SAI was the predictor variable according to the following algorithms:

$$SAI\_2050 = 0,752 * SAI + 45,837 \qquad (R^2 = 0,813) \qquad (2)$$

$$SAI\_2030 = 0,772 * SAI + 33,471 \qquad (R^2 = 0,8023) \qquad (3)$$

The selection of the viticultural areas affected by drought was made taking the threshold of 65 days when the topsoil is dry (Costantini, 2007).
According to the three scenarios, 65% of Italian viticultural areas (vineyards and heterogeneous agricultural areas with vineyards) are at present affected by drought (with remarkable regional differences), the percentage rises to 86% in the year 2030, and reaches 99.6% in the 2050s, when only some very limited areas of northern Italy will remain excluded.

2.2. Presentation of the evolution scenarios

Assuming these conditions of pedoclimatic evolution, the hypotheses explored in the cost-benefit analysis regarded:
a) maintenance of the 'traditional' root stocks (*ex ante* scenario), which do not adapt to the new pedoclimatic conditions. The viticultural ecosystem does not react to climate change or responds with strong limitations of the yield capacity. For this reason, the wine-growers are constrained to make decisions that involve rationalization of the use of water (irrigation when needed).

b) introduction of the 'innovative root stocks' (*ex post* scenario), which adapt to the new pedoclimatic conditions or mitigate the negative effects. The viticultural ecosystem responds to climate change becoming more flexible (or resilient), with an economically positive effect in comparison to the 'traditional root stocks'.
In the *ex ante* scenario has been developed three different hypothesis regarding the use of water (irrigation regime) to compensate the shortage of natural water supply:
a. non-irrigated;
b. averagely irrigated (1 irrigation when needed);
c. fully irrigated (2 irrigations).
Such different irrigation regimes determine different revenues and costs. Stabilizing the yield, the revenues increase with irrigation as the compensation of water stress ensure a better grape quality and grape value increase overcompensate cost increase.
The analysis considered three time scenarios of pedoclimatic evolution - status quo, 2030 and 2050 – and two areas in Italy. The areas considered for the cost benefit analysis of the substitution of traditional rootstock with rootstock resistant to drought are the North-East regions and Sicily in the south. This choice was made to consider two very different conditions, which reflect the wide pedoclimatic differences characterizing the Italian viticulture.

3.3. Cost-benefit analysis

The economic effects of the rootstocks studied by the Ager-Serres project was analyzed by means of a cost–benefit analysis applied to the substitution of the vineyards planted using the traditional rootstock 1103P with vineyards planted on the M4 rootstock (Pennisi, 1985; Florio, 2002; Pennisi and Scandizzo, 2003). The balances were identified according to the standard accounting scheme (RICA-FADN), attributing the earnings and outgoings.
The details of the farm earnings and costs were grouped in the categories of the simplified revenue account (RICA, 2013) relative to the productive cycle of the grape.
For the analysis of the *ex ante* scenario, a typical vineyard of Cabernet Sauvignon was identified, in which the normal cropping operations typical of the production of a premium wine are adopted.
The grape price was determined applying a positive differential compared to the average market price. Such differential reflects the specific value of grape for premium wine production. The average market price was assumed corresponding to 0.50 in North-East and 0.40 in Sicily. The positive differential applied varied according to the irrigation regime: 10% non-irrigated; 20% averagely irrigated; 30% fully irrigated.
In the *ex post* scenario the multiyear data obtained from the experimental fields were utilized. In this way it was possible to obtain the average benefits and average costs of the cultivation and full production phases of the considered scenarios.
Analysis of the earnings was done through an appropriate algorithm normally used by the wine-producers' cooperatives for the determination of grape price, which takes into account the principal parameters of evaluation of its quality (°Brix, pH, anthocyanins):

$$P = P^* + \{\frac{(P^c - P^*)\ 0{,}6\ (Brix^c - Brix^*)}{(Brix^c - Brix^*)} + \frac{(P^c - P^*)\ 0{,}2\ (Ant^c - Ant^*)}{(Ant^c - Ant^*)} + \frac{(P^c - P^*)\ 0{,}2\ (pH^c - pH^*)}{(pH^c - pH^*)}\}$$

Considered the average composition of Cabernet Sauvignon, the following analytical parameters were applied: average values of sugar content of the grape, $Brix^*$ = 19.4 °Brix, pH^*=3.5, anthocyanins, Ant^* = 500 mg/L; the weights attributed to the qualitative parameters were 60% for the sugar content of the grape $Brix^{c,}$ 20% for the acidity pH^c and 20% for the colour Ant^c.

Box 1 - Average values of analytical parameters used in the algorithm.

	North East	Sicily	Standards
°Brix	24.1	24.1	19.4
pH	3.3	3.6	3.5
Anthocyanins	757	716	500

The average market prices P* (euro per kg) were the same as those considered for the *ex ante* scenario: 0.50 in the North-East and 0.40 in Sicily, The P^c parameter was defined increasing P* by 30%; this increase reflects the expected quality of a grape cropped targeting a premium level. The yield per hectare, in the considered scenarios, is the average obtained from the DOC specifications for Cabernet Sauvignon, equal to 13 tons per hectare in the North-East and Sicily. These were compared with the quantitative and qualitative benefits obtained from innovative rootstock of the series M in the experimental fields. The costs were divided into operating costs (fertilizers, pesticides, hiring, insurance), general costs, manual labour costs and other operating costs (RICA, 2013; Ballestero, 1975; Mishan, 1982). Regarding the operating costs, fertilizer costs amount to 280 euro ha^{-1} and those for crop defence are 750 euro ha^{-1}.
The mechanical work is carried out in a hiring regime (Garcia et al., 2004), which covers the case of the farm that makes systematic use of contractors as the productive structure is fragmented, and those autonomous that operate in conditions of maximum efficiency; such costs sum up to 1760 euro ha^{-1} in the *ex ante* scenario and to 1640 in the *ex post* scenario (due to the reduced needs for green pruning). As regards the use of irrigation, the farms averagely irrigated do one irrigation a year that corresponds to a cost of 200 euro ha^{-1}, while on those fully irrigated, applying two irrigations on average, the cost rises to 400 euro ha^{-1}.
Insurance costs are estimated as 5% of the value of the earnings. The general expenditure for energy, contributions to drainage and commercialization of the products, amounts to 300 euro ha^{-1} in North East and 290 euro ha^{-1}in Sicily. The manual labour considered is that supplied by a salaried worker at an hourly cost equal to 15 euro h^{-1} in North East and 13,3 in Sicily. The winter pruning takes around 100 hours ha^{-1}, to which is added 20 hours ha^{-1} of topping and surveillance. The complex of the planting cost generate a depreciation cost by year equal to 1,000 euro ha^{-1} in North East and 800 euro ha^{-1} in Sicily.
Before applying the cost benefit analysis of substitution of traditional vineyards with the innovative ones, the economic performance of vineyard planted on the 1103P rootstock (with the three different irrigation regimes) and on the M4 rootstock was individually evaluated computing the Net Revenue (NR) of the crop in the full production phase and the Net Present Value (NPV) of the entire life cycle of the vineyard (30 years).The Net Revenue of the vineyard has been computed as follow:
NR = Value of Production – total cost by year – depreciation cost
The Net Present Value has been computed as follow:

$$NPV\ (BN) = \sum_{t=0}^{n} a_t\, bn_t = \frac{bn_0}{(1+i)^0} + \frac{bn_1}{(1+i)^1} + \cdots + \frac{bn_n}{(1+i)^n}$$

Where the *bn* is the difference between revenues and cost during each year of the lifecycle of the vineyard, i, the discount rate and a_t the discount factor.
The cost benefit analysis of substitution of traditional rootstocks with the innovative ones has been carried out computing the Net Present Value of the flow of net earnings coming from such substitution. The net earnings obtained from adoption of the innovative rootstocks derive from the increased earnings obtained and deducting the added costs, which cover the earnings lost for the substitution of the traditional root stocks with the innovative root stocks. The added costs, of 9,000 euro ha^{-1}, are ascribed: on the one hand, to the labour used for the uprooting

operations of the traditional root stocks in the vineyard and the planting of the innovative root stocks, and the cost of the new cuttings; on the other to the loss of income, connected to the entry into production of the new root stocks, which takes into account both the earnings differential obtained between the innovative and traditional root stock, and the phases of increasing production (0% in the first year, 30% in the second, 70% in the third) and full production (from the 4th year onwards).
The economic evaluation of the cost effectiveness of the investment in a vineyard planted on M4 rootstock, with duration *n* taken as 30 years, was therefore determined from the Net Present Value of the cost-benefit differential computed for each year (y) of the life cycle of the traditional vineyard as follow:

$$NPV\ (Sy) = \sum_{t=0}^{n} a_t\, S_t = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \cdots + \frac{S_n}{(1+i)^n}$$

Where St is the net earnings obtained from adoption of the innovative rootstocks in the t^{th} year of the life cycle of the new vineyard, i, the discount rate and a_t the discount factor.
For a given comparison, if the result of the NPV (Sy) > 0, then the substitution of the traditional vineyard is economically sustainable, while if the result of the calculation is NPV < 0, the substitution is not practicable. The rate of interest of acceptance (opportunity cost) used was 5%, in line with the current market of monetary values. Two hypotheses of between 2% and 8% were then considered.

4. RESULTS

Table 1 clearly shows differences in revenues between the two areas. Indeed the North-East has considerably higher revenues compared to Sicily in all the scenarios examined. We can also notice an unambiguous hierarchy of revenues of 1103P in different irrigation regimes (non-irrigated vineyards have lower quality grapes due to water stress that is not compensated by cost reduction). In Sicily, the low level of prices in the case of no irrigation determines a negative net revenue. More importantly, M4 rootstock determines higher vineyard revenues compared to traditional rootstocks in all irrigation regimes in both areas, even if the revenue level is very different. A potential superiority of M4 over 1103P can be assumed, which should be confirmed by a thorough financial analysis. In particular, our data highlight that M4 results in higher revenues compared to the best situation of 1103P of roughly 40% in the North-East and more than 80% in Sicily.

Table 1 - Vineyard net revenue by rootstock and irrigation regime (€/ha): full production phase net of mortage

	North East	Sicily
1103P no irrigation	902	- 46
1103P medium irrigation	1320	368
1103P full irrigation	1737	542
M4 (no irrigation)	2440	995
Variation - M4 vs:		
1103P no irrigation	1.538	1.041
1103P medium irrigation	1.120	627
1103P full irrigation	703	453

Table 2 reveals that financial performances of North-East vineyards are clearly higher than Sicilian vineyards, in line with the net revenue differences. In particular, in the North-East in the case of discount rates above 2% it is advantageous to invest in both rootstocks with any irrigation regime, highlighting that investments in M4 have a particularly high profitability, with an internal rate of return of 7.5% compared to 5.15% in the fully-irrigated 1103P. The financial analysis of Sicily data also shows that the lower net revenues correspond to flows of benefits and costs that for 1103P (not irrigated and partially irrigated) do not always determine vineyard profitability. Fully irrigated vineyards with the traditional rootstock present a positive net revenue only with very low discount rates, while the innovative rootstock allows a full profitability also with discount rates up to 3%, revealing a financial performance clearly superior to the traditional rootstock even if inferior to North-East vineyards. The financial analysis also reveals a clear advantage from substituting, in drought-risk areas, traditional rootstocks with the innovative ones at the time of vineyard renewal (i.e. after 30 years). In addition, the superiority in terms of profitability of vineyards planted on M4 compared to irrigated vineyards on 1103P could increase in the case of a rise in irrigation costs. Finally, we should stress that in Sicily the M4 rootstock represents the only chance to have a full cost-effectiveness in planting a vineyard at a reasonable opportunity cost level.

Table 2 - Financial analysis of vineyards performance by rootstock and irrigation regime

	Internal rate of return (%)	Net present value (NPV) by discount rate (€)		
		2%	5%	8%
North East				
1103P no irrigation	2,1	508	-10365	-16212
1103P medium irrigation	3,7	8762	4876	-12374
1103P full irrigation	5,15	17016	593	-8537
M4	7,5	31381	10674	-999
Sicily				
1103P no irrigation	<0	- 17.138	- 20.688	- 22.307
1103P medium irrigation	<0	- 11.449	- 16.951	- 19.724
1103P full irrigation	0,55	- 5.759	- 13.214	- 17.140
M4	3,13	4.723	- 5.769	- 11.500

As depicted in Table 3 differences in terms of actual net revenues with traditional or innovative rootstocks would make an early removal of 1103P worthwhile in specific circumstances. Indeed, also if the NPV of vineyards on M4 is always higher compared to the NPV of vineyards on 1103P, when the vineyard is already planted on 1103P, it may be advisable to collect the flow of positive net benefits of the planted vineyard before planting a new vineyard on M4. Actually, the benefit of an early substitution depends largely on the cost opportunity of the growers and on the vineyard irrigation regime. In general, the cost effectiveness of performing an early substitution is higher with no or reduced irrigation and decreases with the rise of the opportunity cost. It can also be observed that with a 2% cost opportunity it is worth replanting vineyards with innovative rootstock with no or partial irrigation, while with fully-irrigated vineyards with traditional rootstock it is preferable to substitute at the 14th year in the North-East and 25th in Sicily. On the other hand with 8% discount rate substitution is never worthwhile except in the case of vineyards with no-irrigation in North-East, where substitution is cost effective at the 22nd year.

Table 3 - Substitution timing of traditional vineyards by irrigation regime and discount rate: M4 instead of 1103P rootstock

	Discount rate		
	2%	5%	8%
North East			
1103P no irrigation	always	always	after 22nd year
1103P medium irrigation	always	after 19th year	never
1103P full irrigation	after 14th year	never	never
Sicily			
1103P no irrigation	always	after 15th year	never
1103P medium irrigation	always	after 26th year	never
1103P full irrigation	after 25th year	never	never

Analysis of the maps of the drought restrictions for vine cultivation produced by the CRA-ABP (Table 4) emphasizes an extremely significant potential demand for innovative rootstocks. Due to the fact that 14% of North-East vineyards and more than 94% of Sicilian vineyards are currently exposed to drought risk. In addition, these areas are expected to increase in the coming years. Just considering the current situation and that the performance of Cabernet Sauvignon on the traditional and innovative rootstock can be assumed as representative of the average behaviour of other grape varieties, we can estimate that the innovative rootstocks in the considered areas should be around 130,000 hectares. Thus if innovative rootstock replanting ~~would~~ takes place only in vineyards at the end of their natural lifespan (30 years), a renewal process would be activated involving around 6,000 hectares per year. However observing data in Table 3 – which reveal that even for an opportunity cost as high as 5% - it is worth substituting the traditional rootstock in both the no-irrigation and partial irrigation regimes, and therefore imagine that the amount of vineyard renewals could be even higher. Ultimately, use of these innovative rootstocks could also be potentially useful in areas not directly exposed to drought risk as M4 may strengthen resilience of vineyards with unexpected water stress, which will most likely become more frequent in these areas.

Table 4 - Vineyard area exposed to drought (ha)

	Area under vine						
	total	drought risk area					
		current		2030		2050	
		area	share on total	area	share on total	area	share on total
North East	168.868	23641,52	14%	141849,1	84%	165490,6	98%
Sicily	114.298	107.440	94%	112.012	98%	114.298	100%

Source: CRA-ABP

5. CONCLUSIONS AND RESEARCH DEVELOPMENTS

The first exploratory economic analysis of field data produced by the Ager-Serres research project clearly demonstrates the huge interest of the innovative rootstock tested. The innovative rootstock seems to be able to improve the economic performance of vineyards and, in particular, our analysis has revealed that innovative rootstocks allow a full profitability of investments in areas particularly subject to drought risks, such as Sicily. Moreover, substitution of traditional rootstocks with innovative ones, in addition to cost-effectiveness, could be particularly important due to its coherence with general principles of sustainable development (as reducing water use is a core factor of sustainable practices compliance). Furthermore, water-saving policies are gaining increasing attention from public and private standards of environmental performances of wine companies. At the same time, responsible consumers and green associations are demanding higher involvement of companies in reducing the water footprint of final products. Thus the innovative rootstocks appear to be an effective response in providing a high-quality product while ensuring a higher level of profitability, meeting the consumer demand for high-quality products made with environmentally-friendly methods that use fewer scarce resources, such as water. We should also underline that innovative rootstocks can determine important public benefits. Substitution of vineyards on traditional rootstocks could, indeed, reduce irrigation needs deriving from non-substitution in areas exposed to drought risks. This, could likely make public investments for water supply unnecessary in vineyard areas and restrict competition for water use, assisting overall sustainability of the wine sector. Furthermore introducing these innovations is particularly in tune with resilience building strategies, as it enhances the capacity of the vine socio-ecological system to cope with

surprises that are increasingly likely (Folke, 2006). Thus, the need to account for resilience in a changing world is a perspective that should become embedded in all future strategies and policy.
Of course, as frequently happens in the field of innovation diffusion, the adoption of such innovative rootstock could be constrained by several factors. Given the relevant public interest in their adoption, appropriate action should be taken to remove these constraint. Policies at all levels influence the adoption and diffusion of sustainable agricultural systems. In particular, policies to improve the information and knowledge base are likely to lead to particularly important impacts. However improving the information base is not enough; improved access to information, research results, best management practices, other farmers' experiences, and other opportunities for improving management is critical (Lee, 2005). Policies and institutions that encourage the development of competitive and responsive input and output markets in agriculture should be strongly supported as should an increase of public agricultural R&D investments that strengthen private and governmental risk mitigation strategies (Lybbert and Sumner, 2012).
The Ager-Serres project is currently comparing results of North-East and Sicily experiments with data gathered in identical conditions in all Italian regions, encompassing a wide array of pedoclimatic conditions, therefore also considering regions with a very important wine production such as Tuscany, Apulia and Piedmont. A natural extension of the current research would be to replicate the study on a number of other important Italian grape varieties (e.g. Sangiovese or Trebbiano) and in other key producing regions of Italy. Furthermore, future research should try to apply experimental data to specific parameters of vineyards age, in each production area, to assemble a more precise picture of rootstocks substitution profitability and rate, also considering different scenarios in terms of irrigation costs.
Results from such analyses will be extremely useful to support actions required to promote the innovative rootstocks among farmers and to provide the viticulture sector with useful information to plan the production of these rootstocks.

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[1] For a full review of the concept see, among others: Bhamra et al., 2011.