

Article

Not peer-reviewed version

An Integrated Digital Tool for the Choice of Vine Rootstocks

[Alessandro Orlandini](#) , [Maria Costanza Andrenelli](#) , [Sergio Pellegrini](#) , [Giuseppe Valboa](#) , [Rita Perria](#) , [Luigi Tarricone](#) , [Paolo Storchi](#) * , [Alessandra Lagomarsino](#) , [Nadia Vignozzi](#)

Posted Date: 23 April 2026

doi: 10.20944/preprints202604.1655.v1

Keywords: grapevine; rootstock; soil; DSS; precision viticulture; digital agriculture



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC, OpenAlex.

Copyright: This open access article is published under a [Creative Commons CC BY 4.0 license](#), which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

An Integrated Digital Tool for the Choice of Vine Rootstocks

Alessandro Orlandini ¹, Maria Costanza Andrenelli ¹, Sergio Pellegrini ¹, Giuseppe Valboa ¹, Rita Perria ², Luigi Tarricone ³, Paolo Storchi ^{2*}, Alessandra Lagomarsino ¹ and Nadia Vignozzi ¹

¹ Council for agricultural research and economics, Research Centre Agriculture and Environment, Via di Lanciola, 12/A, 50125 Firenze, Italy

² Council for agricultural research and economics, Research Centre Viticulture and Enology, Viale S. Margherita, 80, 52100 Arezzo, Italy

³ Council for agricultural research and economics, Research Centre Viticulture and Enology, Via Casamassima 148, 70010 Bari, Italy

* Correspondence: paolo.storchi@crea.gov.it (P.S.)

Abstract

Rootstock selection is a key component of sustainable vineyard planning, as it determines the vine's capacity to adapt to soil properties and environmental constraints. This study presents Vitis, a modular, microservice-based Decision Support System (DSS) designed to assist winegrowers and professionals in identifying the most suitable grapevine rootstocks for specific pedoclimatic conditions. The rootstock module (SR-Vitis) integrates a process-based model that evaluates 17 widely used European rootstocks by considering soil and site characteristics, including effective rooting depth, texture, coarse fragments, salinity, pH, active calcium carbonate, potential fertility, and risks of waterlogging and water deficit. Input data can be entered manually or retrieved automatically from a georeferenced database through geographic coordinates. The system outputs a list of rootstocks compatible with the given soil and environmental context and provides the user with an automatic report in PDF format. The model was applied to four vineyards located in two contrasting Italian winegrowing regions, Chianti Classico (Tuscany) and Alta Murgia (Apulia), revealing strong agreement between DSS recommendations and rootstocks currently adopted by growers, while also identifying cases where alternative choices could reduce agronomic risk. These results demonstrate the potential of SR-Vitis as an objective and practical tool for enhancing vineyard design, improving decision-making, and supporting viticultural resilience under increasingly variable climatic conditions.

Keywords: grapevine; rootstock; soil; DSS; precision viticulture; digital agriculture

1. Introduction

Viticulture represents a cultural and historical heritage deeply intertwined with human history [1]. Europe plays a leading role in global wine production, consumption and export [2]. In the Mediterranean area, viticulture is a cornerstone of the agri-food sector.

Vineyard management is complex, requiring long-term strategic planning alongside daily and seasonal operational interventions. This complexity arises from the need to consider numerous factors, including climatic and meteorological variables, soil quality and water management. These factors affect the quantity and quality of grape production and are therefore crucial to the economic profitability and long-term sustainability of the wine industry.

Indeed, winegrowers increasingly must cope with environmental variables that are beyond their direct control, whose fluctuations generate considerable uncertainty in technical and production outcomes, with major repercussions for the profit and sustainability of the wine sector. Rootstock selection represents a strategic, long-term agronomic tool for ensuring sustainable agricultural

production, particularly in viticulture. It acts as a biological 'mediator' between the soil and the canopy. In the face of global warming, the appropriate rootstock is essential for managing water stress, salinity, and adaptation to challenging soil conditions. Viticulture is strongly influenced by climate crisis: rising temperatures and changes in rainfall patterns pose increasing difficulties for the agronomic management of vineyards. It is therefore essential to evolve agricultural techniques [3–6].

The practice of grafting gained historical significance in Europe following the phylloxera outbreak in the late nineteenth century. Grafting enables the combination of phylloxera-resistant rootstocks, derived from American *Vitis* species, with the fruit quality of the Eurasian species *Vitis vinifera* [7,8]. Today, although often referred to as the “hidden half” of the vine, rootstocks remain the only effective solution against phylloxera and are indispensable in viticulture.

In the twenty-first century, rootstocks are increasingly recognized as a key component in adapting to evolving environmental conditions [9]. While phylloxera resistance remains a critical trait, rootstocks are also selected for resistance to other pathogens and environmental stresses [10].

Despite the complexity of environmental interactions and physiological responses, breeding drought-resistant rootstocks is necessary for sustainable viticulture [11].

Their adaptability to various soil types and their influence on scion vigour and grape composition are also critical selection criteria.

Under specific conditions, different rootstocks can influence the physicochemical and sensory properties of grapes and wines [12]. Furthermore, rootstocks regulate water and nutrient uptake. Their role is therefore fundamental, making the choice of rootstock an indispensable step in adapting agronomic practices to environmental change [13,14] and in satisfying production and market expectations. In this context, identifying the most suitable rootstock is essential for adapting the vine to diverse soil and climate conditions, as well as for modulating the phenotypic response of the scion [15,16].

Given the managerial and environmental complexity of this economic sector, the adoption of decision support systems (DSS) could provide an innovative and strategic tool. In recent decades, the scope of these systems has expanded, with increasing success across numerous sectors. Agriculture stands to benefit significantly from their adoption, with the potential to improve performance, efficiency, sustainability and accuracy of crop choices.

In the context of Agriculture 4.0 technologies, winemakers find themselves at the nexus of a digital transformation that facilitates access to an immense repository of data, with the capacity to markedly enhance decision-making processes [17].

These systems embody sophisticated information-technology tools that facilitate the integration and analysis of a broad spectrum of empirical data derived from both direct observations and statistical and biophysical models. The use of data-driven and process-based models within DSS facilitates the generation of predictions and recommendations, thereby ensuring that decision-making processes are more accurate and timelier [18].

Data-driven models leverage machine-learning methodologies and statistical analyses to discern predictive correlations between environmental variables and agronomic performance. While these approaches offer high accuracy in the presence of large bodies of real-world, high-quality data, they are often limited by the availability of data that systematically link operational decisions to the results obtained. Conversely, process-based models, founded on biophysical principles and natural laws, exhibit superior generalisation capabilities, making them particularly advantageous in circumstances characterised by limited data availability and high environmental variability [19,20].

Their use has been demonstrated to be a promising method for translating the variety of available data into robust decision-making processes for viticulture. These models facilitate the integration of biophysical relationships, decisions and exogenous variables that influence vineyard outcomes [21] and, as such, this paper focuses exclusively on them.

Despite considerable technological advances, operational decisions in the wine sector frequently remain anchored in subjective evaluations – often based on personal experience and traditional advice – due to the slow integration of data into decision-making processes [22]. A review of the

relevant literature and industry practices reveals a paucity of dedicated DSS for rootstock choice. Moreover, the DSS currently available for rootstock choice is geographically limited and designed for specific contexts. Their evaluation process still largely relies on manuals, expert consultations or tables provided by research institutes, without the aid of computerised systems accessible to all users.

In addition to numerous static tables and guidelines, only two interactive online tools are currently available, with two additional tools under development:

- The Grapevine Rootstock Selector Tool (GRST) was developed in Australia by Yalumba Nursery and subsequently updated and released by Wine Australia in 2016, before being upgraded in 2019 [23].
- The *Árbol de Decisión para Elección de Portainjertos* (ADEP) was implemented by the Diputación Foral de Álava (Spain) for winegrowers in Rioja Alavesa and the Basque Country [24].
- WANUGRAPE4.0 Rootstock Selector (W4RS) was developed as part of a Spanish public and EU-funded research project [25].
- A MATLAB-based graphical user interface (GUI) was developed as a computational tool to support rootstock selection in Chilean viticulture [26].

This paper presents a digital tool designed to support rootstock choice as part of a broader Decision Support System (DSS), called *Vitis*, for sustainable technical and agronomic vineyard management, providing a practical, immediately applicable tool. The criteria and conceptual model underlying the development of the tool are illustrated, together with the methodological approach and the final interface. The DSS aims to optimize the plant's vegetative-productive balance by suggesting suitable rootstocks, among the 17 most used in Europe, based on specific pedoclimatic characteristics. The use of rootstocks to balance vegetative and reproductive growth represents one of the most sustainable strategic choices in modern agriculture. Fundamentally, an appropriately selected rootstock enables the vine to 'self-regulate' in relation to the soil [27], thereby reducing the grower's reliance on chemical fertilizers and irrigation. The tool is applied to two representative vineyard areas – the Chianti Classico production district (Tuscany, Italy) and the Alta Murgia area (Apulia, Italy) – which serve as case studies. The two territories were selected not only for their geoclimatic differences, but also for the diversity of their viticultural management and winemaking objectives. Examining these two contrasting areas evaluates the instrument's performance under different environmental conditions, demonstrating the methodological framework's broader applicability and robustness.

2. Materials and Methods

The present section outlines the architecture of the DSS *Vitis*, and the model utilized for the selection of rootstock (SR module) with a particular focus on its functionality, data acquisition methodologies and technologies employed.

The criteria adopted for its development were guided by the need to create a functioning prototype, accessible via the web, and easily extendable. In this phase, our primary objective was to facilitate rapid development and deployment, while concurrently minimising infrastructural complexity. Consequently, solutions that offer ease of use, immediate integration, and ready-to-use tools were favoured, thus avoiding technologies that would have necessitated advanced configurations or long implementation times.

2.1. Model for Rootstock Choice

The rootstock choice model used is based on the methodological approach the details of which are outlined below. The model is process-based, integrating pedological and agronomic knowledge. The current version of the model can operate a choice between 17 rootstocks, including Kober 5 BB (K5BB), S.O.4 (SO4), 420 A Millardet et de Grasset (420A), 1103 Paulsen (1103P), 110 Richter (110R), 140 Ruggeri (140Ru), 101-14 Millardet et de Grasset (101.14), 196-17 Castel (196.17), Gravesac, 41 B

Millardet et de Grasset (41B), Fercal, M1, M2, M3, M4, 775 Paulsen (775P) and 779 Paulsen (779P). These rootstocks are chosen from among the most widely used in Europe [28] and the new M series selected in Italy. The model can automatically exclude any rootstocks incompatible with the soil, climate, topographic and management characteristics of the area of interest.

Soil properties involved in the evaluation process include soil rooting depth, soil texture, active calcium carbonate content, salinity, pH, coarse fragments (> 2 mm) content, potential fertility, waterlogging risk and water deficit risk (Table 1). They are evaluated by a systematic approach, assigning them to specific classes to define a soil scenario. The classification is based on threshold values drawn from the scientific literature and validated through experimental evidence [29] (Table 1).

Table 1. Soil and site variables, units, and classification thresholds used by the SR module to assess the site-specific suitability of grapevine rootstocks.

Property	Unit	Classification and range
Rooting depth	cm	Shallow (10 - 50), Moderate (50 - 100), Deep (> 100)
Soil texture (USDA)*	Class	S, LS, SL, L, SiL, Si, SCL, CL, SiCL, SC, SiC, C
Coarse fragment content	% vol	Low (≤ 35), High (> 35)
Potential fertility	Class	Low, Medium, High
Electrical conductivity	dS m ⁻¹	Non-saline (≤ 0.5), Moderately saline (0.5 - 2), Strongly saline (> 2)
Active CaCO ₃	% w	Low (< 5), Medium high (5 - 10), Very high (> 10),
pH		Acidic (≤ 6.5), Neutral (6.5 - 7.3), Alkaline (> 7.3)
Waterlogging risk	Class	High, Moderate, Negligible
Water deficit risk	Class	High, Moderate, Negligible

*USDA: United States Department of Agriculture soil textural classes.

The soil was described based on the profile characteristics down to the effective rooting depth. To classify soil “potential fertility”, intended here as the intrinsic capacity of a soil to support vine rooting and the aptitude to retain water and nutrients, we used an algorithm combining three relatively stable soil attributes: soil texture class, rooting depth, and rock fragments volumetric percentage (skeletal material). This property must be considered to appropriately choose the rootstocks based on the vigour they confer to the vine. The assessment of waterlogging and water deficit risks is currently based on the information provided by the operator. However, a module based on the model proposed by Andrenelli et al. [30] is under development for future implementation, which will allow a more objective estimation of these risks and improve the accuracy of the DSS.

After identifying the relevant classes, the model applies exclusion rules triggered by particularly unfavourable parameters, automatically removing incompatible rootstocks.

These rules enable the model to progressively filter out unsuitable rootstocks, thereby retaining only those compatible with the specific pedoclimatic and agronomic features. This configuration ensures considerable operational flexibility, as both classification thresholds and exclusion rules can be updated in line with new research findings or scientific recommendations.

The acceptance or exclusion of a rootstock is based on information regarding its suitability to different pedoclimatic contexts (Table 2). Research results are often scattered across studies that adopt different methodological approaches, hindering the development of a global or universal understanding of vine rootstock adaptation to soil conditions. The information presented in Table 2 derives from a detailed analysis of multiple scientific sources [14,31–39], and from comparison with local technical documents [40,41] used in different geographical contexts. In cases of conflicting recommendations, priority was given to guidelines from VCR 17 (Vivai Cooperativi Rauscedo), as they are specifically calibrated for Italian pedoclimatic conditions and for the geographical area where the DSS is primarily intended to be applied.

The final output of this tool is a list of rootstocks deemed compatible with the pedoclimatic conditions of a specific site. This list guides users toward a more specialised set of options. While the model primarily focuses on soil-related aspects and secondarily on climate (via the evaluation of waterlogging and water deficit risk), it serves as a valuable starting point for subsequent management decisions, which can then be refined using additional information, such as grape varieties and oenological objectives.

Table 2. Rootstocks suitability to limiting soil conditions. Different colors stand for different levels of ability: (red) low; (orange) medium; (green) high; (white) data not available or not limiting factor. The origin of each rootstock is indicated as follows: (a) *V. riparia* x *V. rupestris*; (b) *V. berlandieri* x *V. rupestris*; (c) *V. berlandieri* x *V. riparia*; (d) others.

Origin	Rootstock	Suitability to					Active CaCO ₃ (%) [*]
		High Potential Fertility	Salinity	Acidic pH	Water logging	Water deficit	
(a)	101.14	Green	Red	Red	Green	Red	9
(b)	1103P	Red	Green	White	Yellow	Green	17
(b)	110R	White	Red	White	Red	Green	17
(b)	140Ru	Red	Yellow	White	Red	Green	40
(b)	775P	Red	Yellow	Red	Red	Green	19
(b)	779P	Red	Yellow	Red	Red	Green	16
(c)	420A	Green	Red	White	Yellow	Yellow	20
(c)	K5BB	White	Red	White	Yellow	Yellow	20
(c)	SO4	White	Red	White	Yellow	Yellow	17
(d)	196.17	Red	Green	White	Yellow	Green	6
(d)	41B	White	Red	Red	Red	Green	40
(d)	Fercal	White	Yellow	White	Yellow	Yellow	40
(d)	Gravesac	White	Red	Green	Yellow	Yellow	5
(d)	M1	Green	Yellow	White	Green	Yellow	35
(d)	M2	Red	Green	White	Yellow	Green	25
(d)	M3	Green	Red	White	Yellow	Yellow	22
(d)	M4	White	Green	White	Yellow	Green	25

^{*}Suitable up to.

2.2. DSS Architecture and Graphical User Interface

2.2.1. Modular Architecture and Microservices

The DSS Vitis has been designed to progressively integrate various models dedicated to the monitoring and optimisation of agronomic parameters relevant to grapevine cultivation. The system adopts a modular, scalable architecture based on distributed services and is designed according to the microservices paradigm, where each model operates as an independent unit accessible through HTTP requests via RESTful APIs. This approach ensures high interoperability and flexibility, allowing the use of individual models within the DSS and their integration into external software environments. Within the DSS, each model constitutes an autonomous module that can therefore be selected and executed independently of the others (Figure 1).

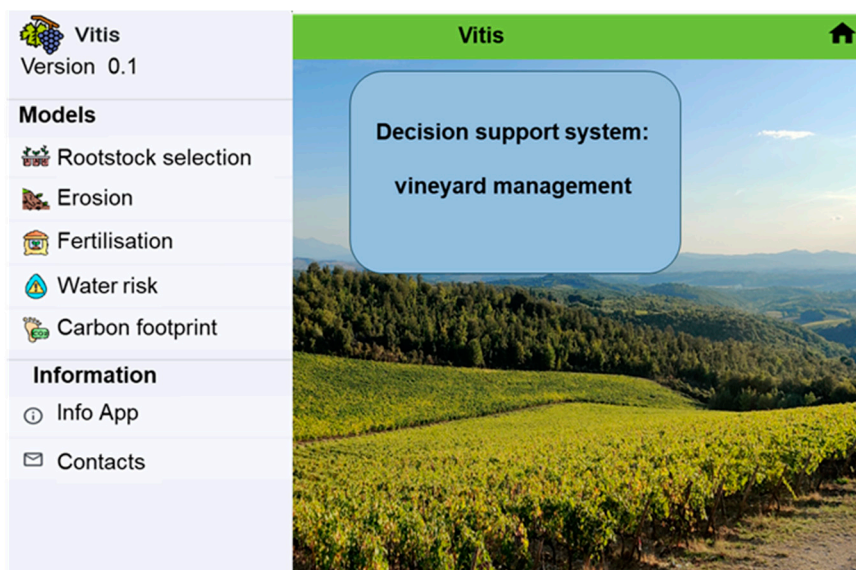


Figure 1. Vitis home screen and module menu. The left sidebar lists the different available models: Rootstock selection (SR-Vitis), Erosion, Nutrition, Water risks (water deficit and waterlogging), and Carbon footprint.

At present, the system is equipped with the module for the choice of rootstocks, which is implemented as a RESTful service using GET requests and integrated into a Progressive Web App (PWA) [42,43] developed with the Flet framework (v0.26.0). From an infrastructural standpoint, the application's backend adopts the ASGI (Asynchronous Server Gateway Interface) standard to optimize system performance by enabling concurrent request processing and reducing data processing latency.

2.2.2. Data Acquisition

To ensure maximum operational flexibility and adaptability to different contexts, the interface allows users to manually enter the data required to run the model (Figure 2a). This feature is essential for producing customized outputs that reflect the site-specific characteristics of each vineyard, leveraging local user knowledge, and supporting targeted decision-making.

In cases where one or more required data points are not supplied, the system responds by displaying the indication "N/D" (No Data) for the missing variables, while still generating a result. In such cases, the system automatically excludes those rootstocks for which the missing variable would be a limiting factor from the list of recommendations (Figure 2b). The model description can be found in Section 1.

For greater flexibility, the model was built with the ability to acquire the required data from external databases, either as an alternative or in addition to user data. Specifically, the model can optionally connect to a PostgreSQL database with the PostGIS extension, which contains georeferenced information about the soil and agronomic characteristics of the vineyards. The dataset integrated into the database, developed by Barbetti et al. [44], is currently limited to the Tuscany region and is used here for demonstration purposes. The user interface allows the input of a pair of geographic coordinates (Figure 2a), triggering an analytical process that leverages PostGIS's advanced spatial operations. The system identifies any available data in the database relevant to the specified location and returns the values of the variables required by the model. Upon completion of the rootstock selection model, once the required data is entered, users can save the results by exporting them to PDF format (Figure 2c). The report includes a textual summary of the analysed parameters and a list of the most suitable rootstocks.

a) Data-entry interface: The interface is titled "Rootstock selection" and includes a "Map" button, "Vineyard" label, and input fields for "Latitude (N)" and "Longitude (E)". A "Database" button is also present. Below these are two columns of input fields for soil properties: Rooting depth (cm) [100], Skeletal material (%) [20], Active CaCO₃ (%) [7], Electrical conductivity (dS/m) [0.2], pH [8.3] on the left; and Soil texture [Silty clay loam], Waterlogging risk [Negligible], Water-deficit risk [High] on the right. A green arrow button is at the bottom.

b) Synthesis of soil properties with recommended rootstocks: This screen shows the same "Rootstock selection" title. It displays the soil properties from (a) as selected values: CaCO₃ content [Medium high], Water stress [High], pH [Alkaline], Waterlogging [Negligible], Salinity [Non-saline], and Potential fertility [Medium]. Below this is a green bar labeled "Selected rootstocks" with a text box containing "M2 - M4 - 196.17 - 41B - 1103P - 110R - 140Ru - 775P - 779P". A green arrow button is on the left and a "Save" button is on the right.

c) Auto-generated PDF report for the T-2 vineyard: The report is titled "Rootstock selection module" and "Vineyard: T - 2". It lists the coordinates: "Coordinates: Latitude (N) 43.400, Longitude (E) 11.457". It then lists soil properties: "Rooting depth: Medium", "Soil texture: Silty clay loam", "Skeletal material: Low", "Potential fertility: Medium", "Active CaCO₃: Medium high", "Salinity: Non saline", "pH: Alkaline", "Waterlogging risk: Negligible", and "Water-deficit risk: High". At the bottom, it lists "Suggested rootstocks: M2 - M4 - 196.17 - 41B - 1103P - 110R - 140Ru - 775P - 779P".

Figure 2. Workflow of the SR-Vitis for rootstock choice: a) data-entry interface; b) synthesis of soil properties with recommended rootstocks; c) auto-generated PDF report for the T-2 vineyard.

2.2.3. Cartographic Module

To enable all system models to access spatial data, the DSS integrates a cartographic module that provides dynamic rendering of raster and vector layers. This component uses the Leaflet.js visualisation library (via Folium and Leafmap) to offer an interactive and intuitive display of geographic data (Figure 3). Users can view geospatial information related to their area of interest and upload files in TIFF, SHP, ZIP, and GeoJSON formats, thereby supporting broader integration of datasets from external sources. It is important to note that the primary function of this module is data visualisation, rather than direct spatial data processing.

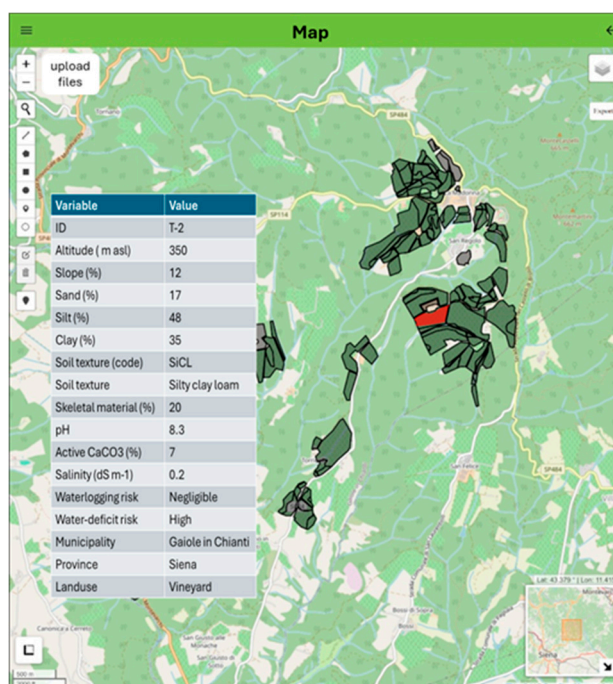


Figure 3. Geospatial module of the DSS (Map). Interactive map with vineyard polygons; the attribute popup summarises soil and site variables for the selected unit.

2.2.4. Technologies and Online Deployment

The entire system was developed using the Python 3.12.2 programming language, with the integration of JavaScript for cartographic features and SQL for database interfacing. The source code is maintained in a private GitHub repository. The API implementation employs the FastAPI framework (v0.115.6), and communication among the various architectural components occurs via the HTTP/HTTPS protocol, with asynchronous task management handled by the `asyncio`, `httpx`, and `tenacity` frameworks. The system's deployment as a web application based on ASGI occurred on the Railway platform, which hosts the PWA front-end, the RESTful APIs, and the PostgreSQL database with PostGIS. Railway was chosen for its ability to automatically scale services according to workload, thus optimising computational resources.

In the final version, all models will be interoperable and capable of dynamically exchanging data to enhance the quality of the analyses and provide users with more detailed, integrated information. Furthermore, plans are underway to expand the database to include national-scale data.

The PWA is available for trial upon request.

2.3. SR-Vitis Practical Application at Vineyard Scale

The SR module of Vitis was tested on a single vineyard scale to evaluate its reliability in the choice of rootstocks based on local soil conditions. The study involved two Italian wine-growing regions with a strong oenological vocation: Chianti Classico in Tuscany, characterised by well-drained, hilly soils and a temperate sub-Mediterranean climate with hot summers and mild winters; Alta Murgia in Apulia, corresponding to the inland area of the Castel del Monte DOCG, with Mediterranean climate strongly limiting water availability during the vine vegetative development.

In each region, two different vineyards were selected to represent the local pedological and morphological variability. Both the Tuscan vineyards belong to the Barone Ricasoli estate in the municipality of Gaiole in Chianti (SI) (T-1: 43° 22' 58.8" N, 11° 26' 09.6" E; T-2: 43°24'00.0" N, 11° 27' 25.2" E); the Apulian vineyards belong to the Torrevento winery, in the municipality of Corato (BA) (P-1: 41° 05' 36.1" N, 16° 20' 23.6" E; P-2: 41° 05' 01.6" N, 16° 21' 23.0" E). Soil and climate data were collected from in-situ soil surveys and local weather stations.

The cultivars adopted in the selected vineyards were Sangiovese in Tuscany while Nero di Troia and Primitivo in Apulia. Interviews conducted with the farm technical staff about the rootstocks present in the various vineyards revealed that 110R and 420A were used in Tuscany, while only 775P was used in Apulia.

2.3.1. Experimental Data

Soil physical and chemical properties were determined from samples collected from horizons of the representative soil profiles. Total organic carbon (TOC) was assessed by dry combustion with a ThermoFlash 2000 CN analyzer, after decarbonation with 10% HCl [45]. The active calcium carbonate (CaCO₃) content was determined according to the Drouineau method as described by Loeppert and Suarez [46], by reaction with 0.1 M L-1 NH₄-oxalate and colorimetric titration with 0.02 M L-1 K-permanganate.

Soil pH was measured potentiometrically in a 1:2.5 soil/water suspension. Soil electrical conductivity was measured in a 1:2 soil/water extract after two hours of shaking followed by overnight sedimentation. Soil particle size distribution was determined by the X-ray attenuation method, using the Micromeritics Sedigraph 3100 equipment [47] and classified according to the USDA system. The volumetric abundance of coarse rock fragments (skeletal material) was assessed in the field in conjunction with the morphological description of the soil profiles and, where possible, corroborated by laboratory data. The effective rooting depth was identified based on the presence of soil horizons that prevented root penetration for physical or chemical reasons.

Finally, the risks of waterlogging and water deficit were quantified using the model proposed by Andrenelli et al. [30].

3. Results and Discussion

The four investigated vineyards show different soil, climate, topographic and agronomic conditions (Table 3).

The Tuscan vineyards (T-1 and T-2) are located at an altitude of about 400 m a.s.l., on moderately sloping hillsides (about 8 %), south-east facing, and are characterized by soils with a moderate effective rooting depth, low coarse fragment content, alkaline pH, and a medium high active calcium carbonate content in T-2. Texture is sandy loam in T-1 and silty clay loam in T-2. Electrical conductivity is low, indicating the absence of salinity issues. Due to the good permeability of the soil profile, the risk of waterlogging is negligible, whereas water deficit is moderate in T-1 and high in T2. The potential soil fertility is estimated to be moderate in both cases.

The Apulian vineyards (P-1, P-2) are situated on flat areas, at an altitude of about 350 m a.s.l., and characterized by soils with silty clay loam (P-1) and clay loam (P-2) texture. In both Apulian sites, the risk of waterlogging is negligible, whereas the risk of water deficit is high, owing to the low rainfall typical of the local climatic context.

At P-1, the soil profile is deep, devoid of coarse fragments and carbonates, with a neutral pH and high estimated potential fertility. P-2 features a moderate effective rooting depth, high coarse fragment content, and high total carbonate but low levels of active calcium carbonate. The pH is alkaline, and no salinity issues are present. The potential fertility is low, limited by both the moderate rooting depth and the high soil stoniness.

For each vineyard, the DSS generated a list of rootstocks tailored to the site-specific pedoclimatic characteristics (Table 3).

Table 3. Site-specific suitability results for the four case-study vineyards (T-1, T-2, P-1, P-2): soil and site classes and DSS-recommended rootstocks.

Property	Vineyards			
	T-1	T-2	P-1	P-2
Textural class	Sandy loam	Silty clay loam	Silty clay loam	Clay loam
Rooting depth	100	100	110	80
Coarse fragment	20.0	20.0	0	44.3
Active CaCO ₃	2.6	7.0	0.0	1.13
EC	0.2	0.2	0.2	0.2
pH	8.5	8.3	7.3	8.0
Waterlogging risk	Negligible	Negligible	Negligible	Negligible
Water deficit risk	Moderate	High	High	High
Potential fertility	Medium	Medium	High	Low
Suggested Rootstock	M1	M2	M3	
	M4	41B		
	1103P	K5BB	M2	M4
	110R	SO4	196.17	41B
	420A	196.17	1103P	110R
	Gravesac	Fercal	140Ru	775P
	140Ru	775P	779P	
		779P		
				M2
				M4
			196.17	
			41B	
		M4	41B	
		110R	1103P	
			140Ru	
			775P	
			779P	

In both Tuscan vineyards, the model identified a wide range of suitable rootstocks. For T-1, almost all rootstock options were found to be suitable (16 out of 17), except for 101.-14, which is better suited to conditions of negligible water deficit. In T-2, the model featured a more restricted selection of nine rootstocks. It excluded 101.14, 420A, K5BB, SO4, Fercal, Gravesac, M1, and M3, generally characterized by shallow roots, making them unsuitable for conditions with high water deficits. In the Apulian vineyards the number of suitable rootstocks was considerably lower, particularly in P-1, due to more discriminating soil and climate conditions. In P-1, where soil potential fertility and water deficit risk are high, the system suggested only three rootstocks: 41B, 110R and M4. The remaining were excluded either because unsuitable for counteracting a possible soil-induced excess in vine vigour or because poorly performing under severe water deficit conditions. Conversely, in P2, where the high risk of water deficit is associated with low soil fertility, primarily due to the elevated coarse fragment content, nine rootstocks were deemed suitable, i.e. 1103P, 110R, 140Ru, 41B, 775P, 779P, 196.17, M2, and M4.

The comparison between the SR-Vitis recommended rootstocks and those currently used by vine growers showed agreement in three out of four sites. The suitability of 110R, 420A, and 775P rootstocks selected by our model and already used by vine growers respectively in vineyards T-1, T-2, and P-2, is further confirmed by the literature, where they are highlighted for their ability to combine moderate vine vigour with good water and nutrient uptake efficiency in alkaline-calcareous soils with medium to low fertility [32,48,49].

Only in one case did the model's prediction differ from the farm's choice. The discrepancy concerned the 775P rootstock, currently used in P-1 but rejected by the model as it was deemed unsuitable in terms of induced high vine vigour. As previously mentioned, P-1 and P-2 differed greatly across a wide range of soil properties, including potential soil fertility. The latter was rated as high in P-1 and low in P-2, which was further supported by a number of additional surveyed features of the soil profiles, i.e., soil organic carbon (2.4 % in P-1 vs 0.9 % in P-2) and total nitrogen content (1.9 % in P-1 vs 0.5 % in P-2).

The 775P rootstock is known to induce high vine vigour, which can become excessive in the presence of highly fertile soils [50,51]. For this reason, despite its good adaptability to the physical and chemical characteristics of the soil, our model deemed 775P not suitable for P-1.

The grower may decide to disregard this recommendation based on their production goals and their ability to manage high risk levels through specific management techniques. In fact, the SR-Vitis applies a cautious risk threshold based on a “one-strike-out” approach, according to which the presence of even a single potentially critical factor is enough to exclude a rootstock, thus minimizing agronomic risk.

In vineyards T-1, T-2, and P-2, the model validates the farm’s choices, suggesting that the parameterization used is appropriate for sites with similar characteristics. In P-1, instead, the tool does not agree with the current choice, identifying room for optimization consistent with experimental evidence linking fertile soils to excessive vegetative growth.

In summary, the tool serves a dual function: on one hand, it provides confirmatory support, validating decisions already aligned with soil conditions; on the other, it offers corrective guidance, suggesting more appropriate alternatives when potential imbalances arise. This dual role contributes to a more rational and targeted vineyard planning, finely tuned to the specific characteristics of the soil.

The development of a dedicated tool for rootstock choice represents an opportunity to integrate technological innovation with agronomic tradition. Such a system would streamline the decision-making process by providing scientifically based recommendations tailored to the specific pedoclimatic conditions of individual vineyards. This approach would enhance the effectiveness and sustainability of viticultural practices, while simultaneously marking a significant step forward in the digital transformation of the wine sector.

In this context, the DSS Vitis is designed for broad applicability across the European viticultural landscape. Winegrowers can receive recommendations as soon as basic pedoclimatic and agronomic data are entered or retrieved, making the tool effective during the vineyard planning phase. Its modular architecture allows for the independent updating of decision rules and information layers, while the future integration of additional vineyard management modules will enable the system to evolve over time, in step with the latest research developments and the expansion of available datasets.

The system is not intended to replace decision-makers, but to support their choices through an informed decision-making process, increasing the independence of winegrowers from market forces.

The proposed system shifts the focus away from the traditional approach, which relies primarily on the interaction between scion and rootstock, towards a selection process based on soil characteristics, thereby emphasizing the importance of terroir in investment decisions within viticulture.

In conclusion, modern viticulture stands at a crossroads where tradition meets innovation: on the one hand, vineyard management and rootstock choice require the careful integration of historical knowledge and empirical practices; on the other, the adoption of DSS and advanced modelling offers the prospect of increasingly efficient, resilient, and sustainable agriculture. Future developments will involve expanding spatial data coverage and integrating additional modules, enabling a joint assessment of agronomic, environmental, and management aspects. This will facilitate vineyard management tailored to local conditions and increase resilience to climate and environmental variability. From this perspective, the rootstock choice module represents the first step in a broader journey toward integrated digital tools for viticulture.

Author Contributions: Conceptualization, N.V., S.P. and M.C.A.; methodology, N.V., M.C.A., A.O., P.S. R.P.; software, A.O.; validation, P.S., R.P. and L.T.; formal analysis, M.C.A., G.V.; investigation, N.V., S.P., M.C.A., R.P., P.S., L.T.; data curation, A.O, G.V.; writing—original draft preparation, A.O.; writing—review and editing, N.V., S.P., M.C.A., R.P., G.V., P.S., A.L; supervision, N.V.; funding acquisition, P.A.L., P.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Ministry of Agriculture, Food, Forestry, and Tourism (MiPAAFT) as part of the sub-project “SUVISA-Viticultura” (AgriDigit programme) (DM n. 36510/7305/18 of 20 December 2018).

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data and the tool presented in this study will be available upon request to the corresponding author.

Acknowledgments: The authors thank the Barone Ricasoli S.p.A. Società Agricola and Cantine Torrevento S.r.l. for hosting the trials.

Conflicts of Interest: “The authors declare no conflicts of interest.” “The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results”.

References

1. Unwin, P.T.H. *Wine and the Vine: An Historical Geography of Viticulture and the Wine Trade*. Taylor and Francis. **2005**. Routledge. <https://doi.org/10.4324/9780203013267>.
2. International Organisation of Vine and Wine. 2024 World Wine Production Outlook—OIV First Estimates, Dijon, France, 29 November 2024. Available online: https://www.oiv.int/sites/default/files/default/2024-11/OIV_2024_World_Wine_Production_Outlook.pdf (accessed on 9 August 2025).
3. Gentilesco, G.; Coletta, A.; Tarricone, L.; Alba, V. Bioclimatic Characterization Relating to Temperature and Subsequent Future Scenarios of Vine Growing across the Apulia Region in Southern Italy. *Agriculture*, **2023**, *13*(3), 644. <https://doi.org/10.3390/agriculture13030644>.
4. Hannah, L.; Roehrdanz, P.R.; Ikegami, M.; Shepard, A.V.; Shaw, M.R.; Tabor, G., Zhi, L.; Marquet, P.A.; Hijmans, R.J. Climate change, wine, and conservation. *In Proceedings of the National Academy of Sciences*, Washington, D.C., **8/4/2013**, 110 (17), 6907–6912. <https://doi.org/10.1073/pnas.1210127110>.
5. Schultz, H.R. Global Climate Change, Sustainability, and Some Challenges for Grape and Wine Production. *Journal of Wine Economics*, **2016**, *11*(1), 181–200. <https://doi.org/10.1017/jwe.2015.31>.
6. Van Leeuwen, C.; Destrac-Irvine, A.; Dubernet, M.; Duchêne, E.; Gowdy, M.; Marguerit, E.; Pieri, P.; Parker, A.; De Rességuier, L.; Ollat, N. An Update on the Impact of Climate Change in Viticulture and Potential Adaptations. *Agronomy*, **2019**, *9*(9), 514. <https://doi.org/10.3390/agronomy9090514>.
7. Keller, M. *The science of grapevines* (3rd ed). Academic press, London. **2020**.
8. Ollat N.; Yobrégat O.; Lacombe T.; Rienth M.; Julliard S., Cookson S.J.; de Miguel Vega M.; Papura D.; Marguerit E. Grafting, the most sustainable way to control phylloxera over 150 years. In *Proceeding of Ives Conference Series*, 45. World Congress of Vine and Wine, Oct **2024**, Dijon, France <https://hal.science/hal-04744516>.
9. Ollat, N.; Bordenave, L.; Tandonnet, J. P.; Boursiquot, J. M.; Marguerit, E. Grapevine rootstocks: Origins and perspectives. *Acta Horticulturae*, **2016**, *1136*, 11–22. <https://doi.org/10.17660/ActaHortic.2016.1136.2>.
10. Prinsi, B.; Simeoni, F.; Galbiati, M.; Meggio, F.; Tonelli, C.; Scienza, A.; Espen, L. Grapevine Rootstocks Differently Affect Physiological and Molecular Responses of the Scion under Water Deficit Condition. *Agronomy* **2021**, *11*, 289. <https://doi.org/10.3390/agronomy11020289>.
11. Zhang, L.; Marguerit, E.; Rossdeutsch, L.; Ollat, N.; & Gambetta, G.A. The influence of grapevine rootstocks on scion growth and drought resistance. *Theor. Exp. Plant Physiol.*, **2016**, *28*(2), 143–157. <https://doi.org/10.1007/s40626-016-0070-x>.
12. Medel-Marabolí, M.; López-Solís, R.; Vásquez-Cerda, M.; Seguel-Rubio, E.; Gil-Cortiella, M.; Seguel-Seguel, O.; Obreque-Slier, E. Grapevine rootstocks mediate the effects of soil salinity on physicochemical and sensory properties of Cabernet Sauvignon grapes and wines. *Applied Food Research*, **2025**, *5*(2), 101073. <https://doi.org/10.1016/j.afres.2025.101073>.
13. Warschefsky, E. J.; Klein, L. L.; Frank, M. H.; Chitwood, D. H.; Londo, J. P.; Von Wettberg, E. J. B.; & Miller, A. J. Rootstocks: Diversity, Domestication, and Impacts on Shoot Phenotypes. *Trends Plant Sci.*, **2016**, *21*(5), 418–437. <https://doi.org/10.1016/j.tplants.2015.11.008>.
14. Marcuzzo, P.; Masiero, L.; Mian, G.; Belfiore, N.; Romano, A.; Lovat, L.; Gaiotti, F. Assessing the Effect of Different Grapevine Rootstocks as a Strategy to Maintain the Yield and Quality of *Vitis vinifera* L. cv. “Glera” Under a Warming Climate. *Aust. J. Grape Wine Res.* **2025**, *39*16510, 15 pages, 2025. <https://doi.org/10.1155/ajgw/3916510>

15. Ollat, N.; Peccoux, A.; Papura, D.; Esmenjaud, D.; Marguerit, E.; Tandonnet, J.P.; Bordenave, L.; Cookson, S. J.; Barrieu, F.; Rossdeutsch, L.; Lecourt, J.; Lauvergeat, V.; Vivin, P.; Bert, P. -F.; Delrot, S. Rootstocks as a component of adaptation to environment. In: *Grapevine in a changing environment: a molecular and ecophysiological perspective*. Gerós H, Chaves MM, Gil HM, Delrot S (eds) Wiley, Chichester, England. **2015**, 68-108. <https://doi.org/10.1002/9781118735985.ch4>.
16. Suriano, S.; Alba, V.; Di Gennaro, D.; Suriano, M.S.; Savino, M.; Tarricone, L. Genotype/rootstocks effect on the expression of anthocyanins and flavans in grapes and wines of Greco Nero n. (*Vitis vinifera* L.). *Sci. Hortic.* **2016**, *209*, 309–315. <https://doi.org/10.1016/j.scienta.2016.07.004>.
17. Zhai, Z.; Martínez, J. F.; Beltran, V.; Martínez, N. L. Decision support systems for agriculture 4.0: Survey and challenges. *Comput. Electron. Agric.*, **2020**, *170*, 105256. <https://doi.org/10.1016/j.compag.2020.105256>.
18. Wolfert, S.; Ge, L.; Verdouw, C.; Bogaardt, M.J. Big Data in Smart Farming – A review. *Agric. Syst.*, **2017**, *153*, 69-80. <https://doi.org/10.1016/j.agry.2017.01.023>.
19. Jones, J. W.; Antle, J. M.; Basso, B.; Boote, K. J.; Conant, R. T.; Foster, I.; Godfray, H. C. J.; Herrero, M.; Howitt, R. E.; Janssen, S.; Keating, B. A.; Munoz-Carpena, R.; Porter, C. H.; Rosenzweig, C.; Wheeler, T. R. Brief history of agricultural systems modeling. *Agric. Syst.*, **2017**, *155*, 240–254. <https://doi.org/10.1016/j.agry.2016.05.014>.
20. Terribile, F.; Bonfante, A.; D'Antonio, A.; De Mascellis, R.; De Michele, C.; Langella, G.; Manna, P.; Mileti, F. A.; Vingiani, S.; Basile, A. A geospatial decision support system for supporting quality viticulture at the landscape scale. *Comput. Electron. Agric.* **2017**, *140*, 88–102. <https://doi.org/10.1016/j.compag.2017.05.028>.
21. Leolini, L.; Bregaglio, S.; Moriondo, M.; Ramos, M. C.; Bindi, M.; Ginaldi, F. A model library to simulate grapevine growth and development: Software implementation, sensitivity analysis and field level application. *Eur. J. Agron.*, **2018**, *99*, 92–105. <https://doi.org/10.1016/j.eja.2018.06.006>.
22. Elsayah, S.; Guillaume, J. H. A.; Filatova, T.; Rook, J.; Jakeman, A. J. A methodology for eliciting, representing, and analysing stakeholder knowledge for decision making on complex socio-ecological systems: From cognitive maps to agent-based models. *J. Environ. Manage.* **2015**, *151*, 500–516. <https://doi.org/10.1016/j.jenvman.2014.11.028>.
23. Grapevine rootstock selector tool Rootstock Selector. (Accessed on 11 April 2026). <https://www.grapevinerootstock.com/>.
24. Elección de patrones o portainjertos para plantación de viña. (Accessed on 11 April 2026). <https://web.araba.eus/es/agricultura-ganaderia/eleccion-de-portainjertos>.
25. Visconti, F.; De La Fuente, M.; Buesa, I.; Escalona, J. M.; Medrano, H.; Miranda, C.; Mirás Avalos, J. M.; Palacios, J.; Pérez-Pérez, J. G.; Ramírez-Cuesta, J. M.; Romero, P.; Santesteban, L. G.; Torres, N.; Uriarte, D.; Parra, M.; Intrigliolo, D. S. Decision support system for selecting the rootstock, irrigation regime and nitrogen fertilization in winemaking vineyards: WANUGRAPE4.0. *BIO Web of Conferences*, **2023** *68*, 01032. <https://doi.org/10.1051/bioconf/20236801032>.
26. Campillay-Llanos, W.; De La Fuente-Sáiz, D.; & Ortega-Farías, S. Digitized model for optimal rootstock selection: Proposal for management strategies in viticulture. In Proceeding of IEEE International Conference on Automation/XXVI Congress of the Chilean Association of Automatic Control (ICA-ACCA), Santiago, Chile, 20-23/11/2024, 1–6. <https://doi.org/10.1109/ICA-ACCA62622.2024.10766759>.
27. Darriaut, R.; Lailheugue, V.; Masneuf-Pomarède, I.; Marguerit, E.; Martins, G.; Compant, S.; Ballestra, P.; Upton, S.; Ollat, N.; Lauvergeat, V. Grapevine rootstock and soil microbiome interactions: Keys for a resilient viticulture. *Hortic. Res.* **2022**, *9*, doi: 10.1093/hr/uhac019.
28. Zavaglia, C.; Pecile, M.; Gardiman, M.; Bavaresco, L. Production of propagating material of grapevine rootstocks in the EU and Italy. *Acta Horticulturae*, **2016**, *1136*, 57–62. <https://doi.org/10.17660/ActaHortic.2016.1136.9>.
29. Costantini, E.A.C. *Metodi di valutazione dei suoli e delle terre*. In: Cantagalli (Ed.), *Collana di metodi analitici per l'agricoltura diretta da Paolo Sequi*, vol. 7. Ministero delle Politiche Agricole, Alimetari e Forestali, Firenze, **2006**.

30. Andrenelli, M.C.; Pellegrini, S.; Becagli, C.; Orlandini, A.; Perria, R.; Storchi, P.; Vignozzi, N. A Monthly Water Balance Model for Vineyard Planning and Inter-Row Management. *Agronomy*, **2025**, *15*, 233. <https://doi.org/10.3390/agronomy15010233>.
31. Bianchi, D.; Caramanico, L.; Grossi, D.; Brancadoro, L.; Lorenzis, G.D. How Do Novel M-Rootstock (*Vitis* Spp.) Genotypes cope with Drought? *Plants*, **2020**, *9*, 1385. <https://doi.org/10.3390/plants9101385>.
32. Chen, Y.; Fei, Y.; Howell, K.; Chen, D.; Clingeffer, P.; Zhang, P. Rootstocks for grapevines now and into the future: Selection of rootstocks based on drought tolerance, soil nutrient availability, and soil pH. *Aust. J. Grape Wine Res.* **2024**, *1*-23. <https://doi.org/10.1155/2024/6704238>
33. Corso, M.; Bonghi, C. Grapevine rootstock effects on abiotic stress tolerance. *Plant Sci. Today* **2014**, *1*(3):108-113.
34. Dargie T.; Dor A., Manuel A.; Molly C. Responses of Grapevine Rootstocks to Drought Stress, *International Journal of Plant Physiology and Biochemistry.* **2014**, *6*, 1–6, <https://doi.org/10.5897/IJPPB2013.0199>.
35. Bihari, Z.; Tóth, J. P.; Zsigrai, Gy.; Balling, P.; Fischinger, R.; Éles, S. né. 2016. Rootstock effects on vegetative growth of 'Furmint'. *Acta Horticulturae* **2016**, 1136, 39–44. <https://doi.org/10.17660/ActaHortic.2016.1136.6>.
36. Goldammer, T. The grape grower's handbook: A guide to viticulture for wine production (Third edition), Apex Publishers, Centreville, Virginia, **2018**.
37. Lambert, J.-J.; Anderson, M. A.; Wolpert, J. A. Vineyard nutrient needs vary with rootstocks and soils. *California Agriculture*, **2008**, *62*(4), 202–207. <https://doi.org/10.3733/ca.v062n04p202>.
38. Migicovsky, Z.; Cousins, P., Jordan, L. M.; Myles, S.; Striegler, R. K.; Verdegaal, P.; Chitwood, D. H. Grapevine rootstocks affect growth-related scion phenotypes. *Plant Direct*, **2021**, *5*, e00324. <https://doi.org/10.1002/pld3.324>.
39. Rahemi, A.; Dodson Peterson, J.C.; Lund, K.T. Choosing Grape Rootstock. In *Grape Rootstocks and Related Species*, Springer International Publishing. **2022**, 93–99. https://doi.org/10.1007/978-3-030-99407-5_9.
40. Vivai Rauscedo, Available online <https://vivairauscedo.com/contributi/download/quaderno17-portinnesti-m.pdf> (Accessed on 11 April 2026).
41. PlantGrape. name of the rootstock investigated (es 110 Richter) Available online: <https://www.plantgrape.fr/en/varieties/rootstock-varieties/21> (accessed on 11 April 2026).
42. Pool, R. L. D.; Berkel, J. van; Braak, S.W. van den. A Conceptual Framework for Addressing IoT Threats: Challenges in Meeting Challenges. In: *Proceedings of the 51st Hawaii International Conference on System Sciences*, Honolulu, Hawaii, **01/03/2018**, 2215-2224. Available online: <http://hdl.handle.net/10125/50166>.
43. Rocha, Á. IoT Analytics Architectures: Challenges, solution proposals and future research directions. In *Proceedings of CISTI'2018 - 13th Iberian Conference on Information Systems and Technologies*, 13-16 June 2018, Cáceres, Spain. Conferencia Ibérica de Sistemas y Tecnologías de Información, Piscataway, NJ. IEEE.
44. Barbetti, R.; Criscuoli, I.; Valboa, G.; Vignozzi, N.; Pellegrini, S.; Andrenelli, M.C.; L'Abate, G.; Fantappiè, M.; Orlandini, A.; Lachi, A.; et al. A Regional 100 m Soil Grid-Based Geographic Decision Support System to Support the Planning of New Sustainable Vineyards. *Agronomy* **2024**, *14*, 596. <https://doi.org/10.3390/agronomy14030596>.
45. Violante, P. *Metodi di analisi chimica del suolo*. Ed Franco Angeli. **2000**.
46. Loeppert, R.H.; Suarez, D.L. Carbonate and gypsum. In: *Methods of soil analysis*, Part 3: Chemical methods, SSSA and ASA, Madison, WI, 437–474. Sparks, D. (Ed.), **1996**. <https://doi.org/10.2136/sssabookser5.3.c15>.
47. Andrenelli, M.C.; Fiori, V.; Pellegrini, S. Soil particle-size analysis up to 250 µm by X-ray granulometer: Device set-up and regressions for data conversion into pipette-equivalent values. *Geoderma*, **2013**, *192*, 380–393. <https://doi.org/10.1016/j.geoderma.2012.06.011>.
48. Fort, K.; Fraga, J.; Grossi, D.; Walker, M. A. Early Measures of Drought Tolerance in Four Grape Rootstocks. *Am. Soc. Hortic. Sci.*, **2017**, *142*(1), 36–46. <https://doi.org/10.21273/JASHS03919-16>.
49. Wooldridge, J.; Louw, P. J. E.; Conradie, W. J. Effects of Rootstock on Grapevine Performance, Petiole and Must Composition, and Overall Wine Score of *Vitis vinifera* cv. Chardonnay and Pinot noir. *S. Afr. J. Enol. Vitic.*, **2016**, *31*(1). <https://doi.org/10.21548/31-1-1399>.

50. Pou, A.; Rivacoba, L.; Portu, J.; Mairata, A.; Labarga, D.; García-Escudero, E.; Martín, I. How Rootstocks Impact the Scion Vigour and Vine Performance of *Vitis vinifera* L. cv. Tempranillo. *Aust. J. Grape Wine Res.*, **2022**, 1-16. <https://doi.org/10.1155/2022/9871347>.
51. Yin, Y.; Han, B.; Li, M.; Jia, N.; Liu, C.; Sun, Y.; Wang, Y.; Gao, Q.; Guo, Z. Multiplication, Phenological Period and Growth Vigor of Thirty-One Grapevine Rootstocks and the Role of Parentage in Vigor Heredity. *Horticulturae*, **2023**, 9(2), 241. <https://doi.org/10.3390/horticulturae9020241>.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.